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THE PEGMATITES OF THE RIEBECKITE-AEGIRITE GRANITE OF QUINCY, MASS., U. S. A.; THEIR STRUCTURE, MINERALS, AND ORIGIN.

By Charles H. Warren and Charles Palache.

With Three Plates.

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Introductory.

The general geologic features of the area of riebeckite-aegirite rocks which have an extensive development a few miles south of Boston in the city of Quincy, and to the west of Quincy, in what is known as the Blue Hill reservation, have been brought most fully to the attention of geologists by Professor W. O. Crosby in a well-known memoir.[1] Taken as a whole the igneous rocks of this area form an intrusive mass of rudely elliptical outline measuring some 8 miles in length by 2 to 3 in breadth. They are intrusive into Cambrian strata and are quite certainly precarboniferous. They consist essentially of granite, extensive developments of granite-porphyry and quartz-alkali-feldspar-porphyry, the two last forming a cover over the granite; melano and leucocratic differentiation products; and large masses of apo-rhyolite, intrusive through the other rocks. On account of the economic importance of the Quincy granite it has received considerable attention from petrographers, and of it alone we have a somewhat full petrographical description.[2] Of the other rocks of the area, we have as yet

[1] The Blue Hill Complex, Boston Soc. Nat. History, Occas. Papers, Vol. 4.

[2] See particularly T. N. Dale, Bull. U. S. Geol. Sur., No. 354. Dr. Dale, besides giving a description of the granite, gives also the more important references to the literature of this region.

no adequate petrographical description; but work is now in progress which it is hoped may soon make good this deficiency.

Pegmatitic developments, so common in many granites, were almost unknown in the Quincy granite until some few years ago a mass of pegmatite was discovered in one of the quarries and later two other pegmatites were exposed in another quarry. These pegmatites possess so many features of unusual interest, structurally and mineralogically, both in themselves and in their relations to the enclosing granite, that it has been thought well to publish a detailed description of them; and with this task the present paper is concerned.

Part I. The Enclosing Granite.

Before taking up the detailed description of the pegmatites it will be appropriate to give a very brief summary of the important characters of the enclosing granite. In texture it is equi-granular, hypautomorphic to xenomorphic and of medium to coarse grain. Mineralogically it consists of albite-microcline perthite, quartz, riebeckite with related alkali-hornblendes as yet not exactly determined, and aegirite, with zircon, ilmenite or magnetite, and fluorite as the chief accessories. The characteristics of the various minerals including their textural relations to each other, are quite similar to those of the main part of the pegmatites and it will be unnecessary to go into a detailed description of them here. It may be remarked that the rock shows evidence of having suffered from movements, the minerals being sometimes considerably disturbed or even crushed and recrystallized. The granite enclosing the Ballou and Fallon quarry pegmatites is practically identical with that in the adjoining Hardwick quarry of which Dr. H. S. Washington has given us a chemical analysis[3] which is here reproduced.

SiO_2	73.93
TiO_2	.18
Al_2O_3	12.29
Fe_2O_3	2.91
FeO	1.55
MnO	trace
MgO	.04
CaO	.31
Na_2O	4.66
K_2O	4.63
H_2O	.41
	100.91

[3] Am. Jour. Sci., **6**, 181 (1898).

For a rock so high in silica the iron is notably high; the alkalies are also high, particularly the soda, and account for the abundant soda-iron amphibole and pyroxene present in the rock. MgO and CaO are very low. At least one third of the lime is present as calcite.

Occurrences of Pegmatite in the Quincy-Blue Hill Area.

Up to the present time the following pegmatites have been noted in the area: 1st. Crossing the top of Rattlesnake Hill (east-central part of the area) in a nearly E. W. direction, is a narrow, dike-like vein of pegmatite. It has been traced for about 60 feet and varies from 8 to 10 inches in width. Structurally it is somewhat similar to the pegmatite pipes to be described beyond, having on both margins a zone of fine graphic-granite succeeded toward the center by rather coarse feldspar and quartz containing riebeckite. The center contains a few small crystal pockets and occasional masses of quartz. Another smaller and less regular vein of similar character occurs nearby.

2nd. On the low hill lying south of North Common Hill, Quincy, and just east of the railroad near Pine Hill on the top near its southern brow, are several veins and irregular spots of pegmatitic character. The granite near the top and on the steep southern slope of the hill is capped by a fine-grained granitic rock with a strong tendency toward a porphyritic texture. It dips gently to the south. It is in sharp contact with the granite and along the contact is frequently a rather abundant and coarse-grained development of riebeckite crystals. A few feet north, and underneath the contact in the granite, is an irregular streak of fine-grained granitic rock which contains streaks of much coarser quartz, feldspar, and riebeckite. Its width will average in the neighborhood of two feet and its length, while considerable, cannot be closely determined. While this may be a dike it may also be a detached piece of the overlying fine-grained rock. Its exact nature has not yet been determined. The granite in several places near the contact shows a local coarsening of the grain forming pegmatitic spots made conspicuous by presence of long black riebeckite crystals. Several vein or dike-like streaks of coarse texture also intersect the granite here. The smaller ones vary from one to about four inches in thickness, and are more or less irregular in course, and of only a few feet or yards in length. They consist essentially of feldspar, the usual microcline-microperthite albite, riebeckite, and quartz, and are for the most part considerably coarser in grain than the granite, but also contain a variable amount of fine granitic material. This sometimes forms a streak along the margin and again has an irregular distribution through the

coarser material. The largest vein lies some ten yards north of the contact mentioned and has been traced for at least 75 yards in a nearly E. W. direction. The maximum width of this vein is about 12 inches. Along its strike, at least to the east, in which direction it is best exposed, it tapers to two or three inches in width. Its contacts are well defined, but are in the nature of a sudden coarsening of the granite. Its structure is symmetrical and indicates successive stages of formation. First come bands of coarse material 2 to 5 inches in width. This consists essentially of microperthite, albite, quartz, and riebeckite. The riebeckite is very conspicuous, suggesting tourmaline at first sight, and is the most abundant mineral present. While many of the riebeckite prisms are of small size, the average will measure from 1 to 1½ cm. thick and perhaps 5 cm. long. Many crystals are much larger, measuring 1 to 1½ cm. thick and 10 to 12 cm. long. There is a strong suggestion that there was originally an orientation of these normal to the walls, although they now lie at random and occasionally parallel to them. Although they frequently include feldspar grains, sometimes arranged symmetrically to their own structure, and are deeply indented (or corroded) about the margins, they nevertheless commonly show a fairly good crystal cross-section consisting of *m*, 110 and *b*, 010. They are commonly fractured and the fractures are filled with fine-grained quartz and feldspar. This band is succeeded by a narrow gray streak of much finer grained (1 to 2 mm.) which in turn is followed by a narrow (1–2 cm.) streak of a light brown color, of somewhat coarser grain than the preceding. In the gray streak the riebeckite crystals lie irregularly or, if anything, show a tendency to stand normal to the contact. In the central streak there is a marked orientation parallel to the contact. The microscope shows that this portion of the vein was probably undergoing movement during the process of crystallization. The larger grains are much disturbed in structure, broken, crushed, recrystallized particularly about the margins, and are surrounded by very fine material consisting largely of albite or quartz grains with shreds and particles of riebeckite. Fluorite, ilmenite (or magnetite) and zircon are accessories. There has been considerable kaolinization, and ferruginous decomposition products and carbonates are often present. Except for the tendency of the riebeckite to develop rough prismatic outlines in the prism zone, the minerals are xenomorphic. Aegirite is entirely wanting. It may be noted that the enclosing granite here shows very little aegirite.

These pegmatitic developments are entirely different in character from those to be described later and certainly have a somewhat different origin. While no positive conclusion has yet been reached regard-

ing them, they are believed to be closely connected in their manner of origin with the seams and veinlets occurring elsewhere in the granite which are rich in riebeckite. The formation of these appears to be connected with a period of movement attended by fracturing of the granite and followed by a healing up of the fractures with granitic material. (See general discussion at the end of Part I.)

3rd. Three masses of pegmatite, pipe-like in form, one located in Ballou's and the other two in Fallon's quarry, both quarries being close together on the south central portion of North Common Hill, Quincy. These pipes are, up to date, the only important pegmatites of the Quincy area and are the special subject of this paper.

Occasional small patches of coarser texture than the granite occur in several places in the area. Quite recently several have been found a little to the east of the Ballou quarry and just west of the Hardwick quarry. They are interesting because of a considerable content of molybdenite segregated about their margins.

The Pegmatite of the Ballou Quarry, North Common Hill, Quincy.

The pegmatite in the Ballou quarry was first brought to the attention of mineralogists in 1895, at which time it was examined by Dr. Palache. In 1908 a short description of it was published by Dr. Dale (Bull. U. S. G. S., No. 453, p. 49). Several handsome specimens were cut from it and polished by Mr. F. Wesley Fuller of West Quincy, one of the finest, a complete section, now in the mineralogical collection of Harvard University, being reproduced in Plate 1, Figure 12.

The pegmatite was encountered at a depth of something like 100 feet, and its downward extension, covered by slide material, still remains in the bottom of the quarry. Its position is nearly vertical. Some twenty feet of it have been removed, and while its depth is of course largely conjectural, it seems safe to assume that it is at least 40 or 50 feet. Its form is that of a pipe, in places nearly cylindrical and again rudely lenticular in cross-section with small, irregular branches. It is always concentric in structure and sometimes shows an indistinct radial arrangement of its minerals from the margin inward. Its three shells or zones, although quite irregular in outline and width and intimately blended where they pass into one another, are nevertheless fairly distinct; likewise the contact with the granite is blended although the change from one to the other is sudden. The outer zone is characterized by being considerably darker in color than the granite about it. It is much heavier on one side of the pipe than the other. Its

width is here from 2 to 5 inches and it is marked toward the granite by a greater segregation of dark constituents, chiefly rather slender aegirite or riebeckite crystals. These are arranged to some extent parallel to the margin. The same sort of segregation marks also the inner margin. Between these, the rock in texture and composition resembles closely the granite except that the riebeckite and aegirite are considerably more abundant and the mineral grains are all of larger size. The proportion of aegirite to riebeckite is also greater than in the granite. On one side of the pipe the dark margin is less prominent, the whole zone having practically shrunk to an irregular streak of granitic material in which the dark constituents are very abundant, particularly aegirite.

As a rule the next zone is an irregular one, 1 to 2 inches wide, of fine graphic-granite, containing a few prisms of riebeckite and aegirite. It is the least clearly defined of the zones and passes almost imperceptibly into the main part of the pegmatite. In places the graphic-granite seems to be almost or quite wanting and its place is occupied either by the coarse pegmatite or by a fine-grained mixture of microperthite, quartz, aegirite and a little riebeckite. The main portion consists essentially of a pegmatite or coarse-grained, aegirite granite, carrying some riebeckite, abundant accessory zircon, fluorite, ilmenite, and smaller amounts of other minerals including parisite. The feldspars are an albite-microcline-microperthite of a pale greenish color except where reddish from iron stains. Toward the center where they are the largest, they measure as much as 2 by 2.5 cm. They contain aegirite and riebeckite microlites and black inclusions, also the minute cavities common to all the feldspar of the granite and pegmatites. The quartz, in amount the next mineral present, is without crystal form. Its grains are, except near the center, on the average smaller than the feldspar and of a grayish to white semi-translucent variety. Toward the center the quartz is coarser and more abundant, and at intervals along the length of the pipe, it forms masses two inches or more in thickness and several inches long. In fact the quartz forms a more or less well-defined central core. The aegirite, besides occurring in the form of many small, light-green grains and prisms, forms also abundant, large prismatic individuals of a more or less composite character. These frequently measure 1 cm. in width and 2 or 3 cm. in length, are dark green in color, and form a very striking characteristic of the polished specimens. Riebeckite forms occasional large crystals always more or less completely enclosed by a parallel growth of aegirite. Riebeckite is also usually intergrown in the aegirite crystals and commonly forms a sort of a central core in many of the crystals. These

should in fact be properly termed aegirite-riebeckite crystals. They often contain granular masses of dark purple fluorite mixed with zircon, ilmenite, and quartz, besides decomposition products, chiefly ferruginous in character, which are apt to discolor that portion of the crystal in which they occur. With the coarser material of this zone is more or less fine-grained material. This corresponds to the more abundant fine material to be noted later in connection with the description of the Fallon quarry pegmatites, and consists largely of quartz, microcline, aegirite, zircon, fluorite, ilmenite, a few grains of a nearly colorless, isotropic mineral of very high refractive index thought to be beckelite (see later), besides various secondary products. The larger feldspar grains lying about these fine-grained, zircon-rich areas, are particularly apt to contain small, slender prismoid crystals of albite which are probably later crystallizations, and are connected with pneumatolitic processes. Parts of this fine-grained material are very rich in zircon, and ilmenite (and hematite ?). Alteration develops in this material (see later) a red or brownish-red stain which produces in the rock the appearance of metallic spots. Occasional crystals of zircon attain macroscopic size and are well developed crystallographically. Thin sections of these zircon-rich portions show an interesting relationship between the quartz and zircon. There is a marked tendency on the part of the zircon to form granular intergrowths with quartz. In some instances relatively large zircon grains showing simultaneous extinctions are found enclosed in a quartz grain. In most cases, however, both minerals are granular. The zircon tends to form closely packed aggregates; the grains may have a parallel orientation, although they are often separate and show a more or less well-defined crystal outline. The quartz also shows a tendency to a parallel arrangement of its grains. The quartz-zircon intergrowths are commonly bounded as a whole by a crystal outline, apparently that of a zircon crystal having a short prism with the unit pyramid termination. This outline is usually marked by a string of small zircon grains. The quartz surrounding these areas has frequently a distinct orientation of its crystals perpendicular to the boundaries of the area, a feature that, indeed, may be obscurely visible in the hand specimen. The areas often penetrate adjoining feldspar grains and are closely associated with aegirite. Fluorite, ilmenite, and ferruginous alteration products are also quite abundantly mixed with the zircon and quartz. These zircon-quartz groups evidently belong to the pneumatolitic period and represent, it is believed, zircon crystals which subsequent to their formation suffered more or less recrystallization, replacement by quartz, and perhaps granulation. Figure

14, Plate 2, is a microphotograph of some of these zircon-quartz groups.

Mr. Dale [4] states that these spots consist of magnetite, titanite, epidote, zircon, allanite, fluorite, aegirite and quartz. So far as the present investigation has shown the iron oxide is practically all ilmenite, nor has titanite or epidote been identified in the material at our disposal. Two or three minute, dark reddish grains with a highly resinous lustre have been noted macroscopically, and are not improbably allanite, though this has not been positively ascertained on account of the very meagre amount. Ilmenite and hematite besides the mode of occurrence noted, occur frequently in the form of tabular crystals lying along the sides, or between the cleavages of the feldspars and in the aegirite. The parisite has been observed to occur in crystals, a millimeter in diameter closely associated with aegirite crystals, quartz and fluorite, and clearly belongs, as in the other pegmatites, to the last stage of crystallization of the pipes, and is apparently pneumatolitic in origin. It may be noted that small amounts of galena, sphalerite, chalcopyrite, molybdenite occur in small grains here and there through the pegmatite. For other details relating to the minerals see the later description of the large pipe of the Fallon quarry and the special descriptions beyond.

The Fallon Quarry Pegmatites.

The first pegmatite discovered in the Fallon quarry outcropped at the surface on the south rim of the quarry, where a small remnant of it still remains. From this point the pegmatite, having a similar pipe-like form, and quite similar otherwise to the pegmatite in the Ballou quarry, dipped down into the granite to the north at an angle of about 45°. Following this course, it extended to a depth of about 75 feet (vert.) and then terminated. There is now no trace of it in the bottom of the quarry, but many fragments of it, still remaining on the dump, show clearly its structure and composition.

The second and far more interesting pegmatite follows the same general direction but appears to have flatter dip, and lies below and to the south of the first. The uppermost part yet exposed appears in the southern wall of the quarry about fifty feet below the surface. Here it resembles the first pipe except that it is larger. Along its downward extension, it increases in size, becomes rudely elliptical in cross-section, the major axis being vertical, and contains centrally toward its lower end a remarkable pocket. A few feet below the pocket the pegmatite terminates rather abruptly. Its total length as

[4] Bull. U. S. Geol. Sur., No. 354, p. 50.

now exposed is about 20 feet. The indications are that it may extend upward into the granite toward the south for some distance.

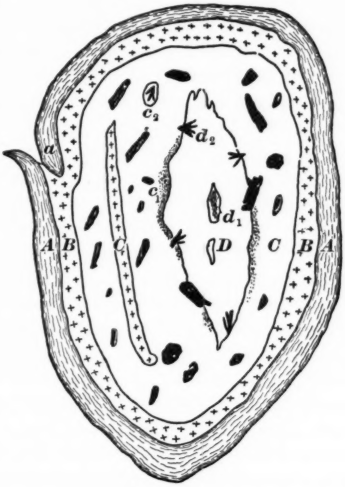

FIGURE 1.

Sketch of cross-section of upper portion of the large Fallon quarry pipe.

A, outer dark colored zone 2 to 5 inches wide, finer in grain than the granite, richer in dark silicates; both margins richer in dark silicates than the middle, and with an arrangement of minerals parallel to the margins. *a*, offset in the band.

B, zone of graphic-granite 2 to 4 inches wide. An intergrowth of microcline-albite microperthite (60 per cent) and quartz (30 per cent) with a few scattered prisms of riebeckite. Passes almost imperceptibly into the next zone.

C, principal zone of unequal, but prevailingly coarse-grained granite or pegmatite; contains a streak of graphic-granite (crossed) and numerous large crystals of riebeckite-aegirite. c_1, concentration of fine zircon, quartz, aegirite rich material next to quartz center. c_2, quartz bleb (2 or 3 inches) with penetrating aegirite prisms.

D, central mass of quartz, grayish-white and massive, penetrated by radiating aegirite groups and large aegirite-riebeckite crystals along margins (d_2) and containing centrally masses of sulphids with fluorite (d_1). One foot wide by two high, roughly.

Compare with Figure 13, Plate **1**.

The concentric structure of this mass is marked as in the other pipes, but little if any radial structure can be seen. The section exposed in the quarry wall shows that in its general characteristics it is closely

similar to the Ballou pipe. Figure 1 is a sketch of this section and with its legend will serve to give a general idea of the character and arrangement of its parts. It should be noted that the demarkation between the zones is not usually as sharp as those in the figure. Figure 13, Plate 1, a photograph, gives also an idea of its structure and appearance.

The dark marginal zone (A in the figure) is here somewhat finer in grain than the granite and much darker in color. There is a distinct arrangement of its minerals parallel to the margins which are also characterized by a greater abundance of dark silicates with which are numerous small grains of black oxides and chalcopyrite. The zone is particularly dark, fine grained, and sharply defined about the upper side of the pipe and in one place is sharply offset. Except in its finer grain, the parallel arrangement of its minerals and the greater proportion of dark minerals, particularly aegirite, which occurs to the exclusion of the riebeckite in some of the slides examined, the rock of this zone appears in thin section under the microscope to be much like the granite; the textural relations of the minerals are the same and their composition appears to be identical.

The zone of graphic-granite (B of Figure 1) seems to be practically continuous just inside the dark band above described and with a width of from 2 to 4 inches passes almost imperceptibly into the main zone of coarse granite or pegmatite within.

In the graphic-granite, individual cleavage surfaces of the feldspar will perhaps average two to three cm. on a side. Their long direction stands generally perpendicular to the margin. In this occurs, sometimes quite plentifully, riebeckite crystals somewhat intergrown with aegirite. The feldspar is a microcline-albite-microperthite. As determined by a Rosival measurement made on two extra-large thin sections it makes up approximately 60 per cent of the intergrowth. The albite appears to be slightly in excess of the microcline and always acts as the host. It strongly predominates about the margins of the crystals and quite generally forms practically the outside of the perthite crystals. The feldspar contains the same microliths of aegirite and riebeckite, the black specks and cavities, as do those of the granite. The contacts of the feldspars (largely the albite member) and the quartz are mutually indented and show what has been described by Pirsson[5] as the "interdented" texture. Minute rounded grains of quartz are common just within the feldspar along the contacts, and suggest chains of tiny islands in appearance. The quartz contains

[5] Am. J. Sci., **23**, 272, 1907.

minute black inclusions and fluid cavities often with moveable bubbles. The extinction of the quartz is usually quite uniform, there being little indication here of strains or crushing. The riebeckite forms rather flat, elongated prisms (1 to 5 mm. broad by 10 to 30 mm. long), but without terminations, the ends being always frayed or continued with aegirite. Aegirite with the exception of the growths on the riebeckite and the microlites in the feldspars is rather sparingly present in this graphic-granite zone.

The zone just described passes almost imperceptibly into the next and principal zone (C in Figure 1) whose leading characteristic is perhaps its irregularity of grain. Running through this material in a direction parallel to the outer margin is a narrow strip of graphic-granite (crossed in figure). It consists essentially of greenish-white crystals of albite-microcline-microperthite; irregular grains of semi-transparent, grayish quartz, long black riebeckite prisms, often much intergrown and practically always surrounded and terminated on the ends by aegirite; aegirite prisms and grains; filling in the spaces between the larger grains is a considerable amount of fine-grained material. This may be light green in color when aegirite is abundant, but more commonly is brownish or brownish red. Occasional small crystal pockets occur in this zone, and in these parisite, fluorite, ilmenite, and secondary riebeckite have been noted. Parisite grains have also been found closely associated with aegirite and quartz, particularly near the quartz center. The fine material forms a more or less continuous network through the zone and in places forms patches of a centimeter or more across. Toward the central quartz zone the fine material seems to increase in amount and immediately about the quartz it constitutes almost a distinct zone itself.

Under the microscope the fine material is seen to consist of variable amounts of quartz, microcline with a little microperthite and albite, aegirite, zircon and ilmenite, magnetite (?), calcite and certain poorly defined decomposition products. The quartz and feldspar occupy spaces of about equal size, but under crossed nicols the feldspar breaks up into a mosaic of small equi-dimensional grains. The quartz shows an undulatory extinction. The aegirite is abundant in the shape of irregular grains lying for the most part in the quartz areas or between the quartz grains and the microcline. Many of the smaller grains lie grouped in such a manner as to suggest that they were once parts of a single crystal. Zircon is very abundant, particularly in quartz-rich portions of the fine material, and while some of the grains will measure 1 to 2 or perhaps 3 mm. on a side and exhibit well-developed short prisms capped by unit pyramids, the majority are small and ap-

pear at least in thin section to lack sharp crystalline form. The larger grains commonly show a fine zonal structure; the small ones are usually clustered, sometimes with parallel orientation and sometimes without, but in the latter case forming a mass often suggesting a larger crystal in outline as in the Ballou pegmatite. The zircon also lies almost wholly in the quartz or between it and the feldspar. Only a few grains have been noted in the microcline. Ilmenite and perhaps magnetite (?) are abundant with the zircon and by their alteration furnish the brownish or reddish-brown stain which often gives these colors the surrounding grains. Calcite is also present here, and is apt to be closely associated with the clusters of zircon, frequently embedding them. Closely associated with the calcite and the stained areas, sometimes quite abundantly, are several other products evidently secondary. One resembles chlorite. Another compact yellowish material has not been identified. The zones in the zircon crystals, particularly the outer zone, are often filled almost to opacity by a fine light brown to red, dusty product. In spots the smaller zircons are also more or less filled with it. What this product is has not been determined.

The feldspar of the coarser-grained portion is the same microcline-albite-microperthite as that in the granite. Its color is usually a pale greenish-white, although it is sometimes reddish from the alteration of small plates of ilmenite or hematite which occur along the cleavage planes. The crystals are rudely rectangular in outline but always with xenomorphic outlines towards the other minerals. In size they vary greatly, ranging from grains 3 or 4 mm. on a side to ones 1.5 by 2 cm., rarely larger. The average probably lies about midway between these figures. As in the granite, the albite strongly predominates about the outside of the grains. Smaller, relatively long and narrow shreds of albite lie in or along the margins and to some extent within the body of the crystals. The usual included microlites of aegirite and riebeckite as well as the minute black particles and cavities are present. A little kaolinization has taken place in portions of the pegmatite.

Aegirite and riebeckite are both abundant. Taking the zone as a whole the former is the most plentiful. The riebeckite forms elongate crystals ranging in size from small grains up to large and very conspicuous crystals, 1 to 2 cm. in diameter and 5 to even 15 cm. in length. The larger crystals are more abundant towards the center and may extend out into the quartz center. Although indented by the feldspar and often including grains of it, the riebeckite, especially in the larger crystals, shows a tendency to develop a crystal cross-

section made up of the forms 110 and 010. Terminal planes are wholly wanting. Without exception the riebeckite is intergrown with aegirite. Commonly in parallel position, though again without definite orientation (c axis in common), the aegirite may occur quite at random in the body of the riebeckite, but it is most abundant about the outside, particularly on the ends, forming an almost or quite continuous shell about the riebeckite. Indeed the ends of the riebeckite crystals are usually continued as a solid mass of aegirite. The aegirite may almost wholly replace the other mineral, there being only a core or a few shreds of riebeckite visible. Besides this mode of occurrence the aegirite is found scattered throughout the coarser parts of the rock and as noted, abundantly in the finer material — and as inclusions in the feldspar. The habit of the aegirite is distinctly toward a delicate columnar structure parallel to the vertical axis, and when broken the fracture is usually splintery. Often there is a marked radial arrangement of the prisms or groups of prisms. This habit is especially common along the contact with the quartz center where clusters of some size occur, the tapering aegirites extending out into the quartz. Occasional separate crystals may be seen lying in the massive quartz 3 or 4 mm. in thickness and several centimeters long. In general throughout this zone the main part of the aegirite, although clearly more closely connected with the quartz in period of formation than with any other mineral, appears to have to some extent preceded it, since a tendency toward automorphic outlines is commonly observed with reference to the quartz. Its color is prevailingly grass-green.

A commonly noted feature of the aegirite-riebeckite crystals is the occurrence in their midst of spots consisting of dark purple fluorite grains, associated with ilmenite, zircon, calcite. These are often stained with ferruginous products.

The central quartz (D of figure) is massive in character, semi-translucent and of a grayish or grayish-white color. Like the rest of the quartz it contains minute inclusions and cavities often with bubbles. Masses of granular galena and sphalerite, one nearly as large as a man's fist, also similar sized pieces of a very dark purple fluorite occur in places through the center of the quartz. Some of these were associated with blue crocidolite like that found in the large pockets.

On the other and western side of the pipe, the succession of zones is essentially the same except that they are not quite so wide.

Through the lower and thicker part of the pegmatite containing the large central pocket the section differs somewhat from that given above, is less regular, and shows sudden changes in character difficult to describe. Going from east to west through its thickest part we meet

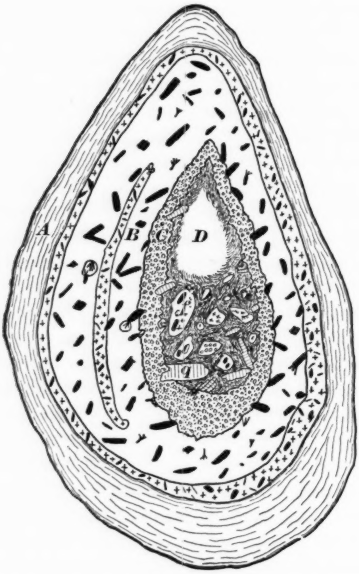

FIGURE 2.

Cross-section through the lower portion of the large Fallon quarry pipe at a point where the central pocket has its maximum development. The vertical dimension is about 10 ft., the horizontal about 6 ft.

A, dark marginal zone, similar in character to that described for Figure 1, but as a whole somewhat less sharply defined, and, in its lower portions, merging almost imperceptibly into the granite without.

B, main zone of the pipe showing a more or less well defined outer band of graphic-granite with streaks and patches of the same in other parts, but in the main consisting of an inequi-granular but prevailingly coarse mixture of microcline-albite microperthite, quartz, large, scattered aegirite-riebeckite crystals, aegirite, zircon, etc. Occasional quartz blebs and small crystal pockets are also present.

C, zone consisting of a porous, inequi-granular mixture of microcline and aegirite. This becomes exceedingly open in texture as the walls of the central pocket are approached and exhibits beautifully free crystallizations of aegirite and microcline on which are implanted crystals of parisite, octahedrite, and ilmenite.

D, microlitic cavity more or less completely filled with quartz crystals, free and attached, fluorite octahedra, fragments of all portions of the surrounding pegmatite, except the dark margin, and the whole embedded in a closely felted mass of beautifully fibrous, grayish-blue crocidolite.

first the dark marginal band (Zone A, Figure 2) here wider than further south, less sharply defined, coarser, and at the lower end merging almost imperceptibly into the surrounding granite.

As in the previous section this zone is succeeded by graphic-granite and uneven though rather coarse granite or pegmatite forming together a zone about 2 feet in width in its eastern and thickest portion, but much narrower on the western side as shown in the figure (B, Figure 2). It will be noted that in the figure a continuous band of graphic-granite (crossed) has been indicated just inside the dark margin; also another strip within the zone running parallel to the boundary. This misrepresents the actual facts to some extent. The graphic-granite is not, so near as could be told, entirely continuous, but is replaced at times, either by the coarse pegmatite, or by a finer, granular rock carrying rounded quartz grains and relatively long, slender riebeckite crystals. Occasionally streaks of large feldspar crystals lie in this latter material with an arrangement rudely parallel to the margins of the zone. These variations seemed particularly strong on the western side of the pipe, but the exact extent, however, of the graphic-granite, etc., was exceedingly difficult to trace accurately and no attempt to do so has been made in the figure. As elsewhere, the gradation of the graphic-granite into the main rock of the pipe is almost imperceptible. The texture and mineral composition of the main part of this zone is practically identical with that of zone B of Figure 1, previously described.

Along a somewhat irregular surface this zone changes rather abruptly both as to texture and mineral composition into the next zone (C of Figure 2). This latter varies considerably in thickness and consists of numerous, relatively large, rudely rectangular crystals of microcline (range of size, 4 or 5 mm. by 2 or 3 cm.) with xenomorphic borders, embedded in a groundmass consisting essentially of microcline and aegirite, quite fine in grain and highly porous in texture. In this groundmass the microcline usually predominates in amount although frequently the aegirite equals or exceeds it. Quartz, while present in the form of small grains in the groundmass, is hardly more than an accessory. As the walls of the central pocket are approached this rock becomes essentially a mass of rather loosely cohering, white or cream-colored microcline crystals and very abundant, dark green to almost black aegirite prisms and needles, the whole filled with small ramifying pockets into which the free ends of the crystals project. Although much of this material is rather course (centimeter) grained there is also a large amount of fine material. The feldspar crystals, although somewhat kaolinized in places, are as a whole remarkably fresh. Some crystals are deeply pitted by solvent action and where

freely exposed, show a secondary growth of clear microcline substance. These later growths contain abundant inclusions of minute aegirite and riebeckite microliths, sometimes being literally crowded with them. The central part of the crystals appear to be rather freer from inclusions than the run of feldspar in the pegmatites. The aegirite occurs crowded in between the feldspars and projects in thickly clustered groups into the free spaces. Its crystals are of all sizes from mere slivers up to crystals 1 cm. broad, 4 cm. thick, and 3, 4 or 10 cm. long. The crystals show a strong tendency toward a composite subradial grouping and great irregularities of development. The larger crystals, to even a greater extent than the feldspar, show evidence of a strong solvent action, some of them being largely eaten away or completely honeycombed. Implanted on the surfaces of the feldspar and original aegirite crystallizations are many beautiful, light green patches of very minute, thickly clustered aegirite crystals of later growth. Occasional quartz crystals occur in the pockets or are embedded in the feldspar and aegirite near the walls of the main central pocket.

Implanted on the surfaces of the feldspar and aegirite, particularly in the pockets, are also : many slender, often richly terminated crystals of the rare mineral *parisite*, often including or closely associated with minute crystals of aegirite ; small quartz crystals ; minute, beautifully crystallized, black octahedrites, occurring as single crystals, in twinned couplets and in clusters ; ilmenite, in the form of minute flat plates or in rosettes of black or grayish black color. Both the ilmenite and octahedrite are often abundant in the cavities formed by solution in the larger aegirite crystals. On the surfaces of the feldspar and closely associated with the parisite, there is sometimes to be seen a pale pink or buff coating of a material composed of tiny clusters of exceedingly minute, feebly translucent grains. The identity of this coating has not been determined, but it is thought to be zeolitic in character. Some of the aegirite and feldspar is also coated with a thin, blackish-red or brown film of iron and manganese oxides.

Inside the zone just described is a remarkable pocket (D in Figure 2) which is unquestionably miarolitic in character. Although a considerable portion had been removed when the pipe was first examined by the writers, the evidence collected shows that it was almost certainly a single continuous cavity of somewhat irregular contours with a maximum width of about 2 feet, narrowing upward along its strike and broader below than above. Its greatest depth vertically, as observed, was about 3 feet. It was continuous with the central mass of quartz exposed above in the quarry wall. It may be noted here, as indicated by the

figure, that the position of the pocket is not exactly central since the zones on the eastern side are considerably thicker than those on the west which measure each only a few inches.

The Central Pocket. — The contents of the large central cavity were most unusual in character and consisted essentially of: quartz crystals of all sizes from exceedingly minute individuals up to great crystals, 10 cm. thick and 30 cm. long; rock fragments of all portions of the pegmatite except the dark marginal zone of sizes ranging from that of a walnut up to that of a man's head; fluorite octahedra, sometimes of large size; and a thickly felted mass of a delicate, grayish-blue crocidolite filled with minute hair-like crystals of riebeckite. The crocidolite embeds, more or less completely, the quartz and rock fragments.

Many of the quartz crystals, particularly the larger ones, were attached to the walls and included the microcline and aegirite crystals of the pocket lining. Others, and possibly the greater number, were wholly enclosed in, and enclose, the crocidolite, or were attached to the fragments. In fact, the crocidolite is literally crowded with quartz crystals, most of them quite small. Much of the quartz has been strongly attacked by solvent action, the crystals being deeply etched, pitted, and in some instances a good part of a crystal has been dissolved away. Some of the quartz is coated with the same black or brownish material noted on the aegirite crystals of the pocket lining. The minerals of the fragments show abundant evidence of solvent action and a later second growth. The riebeckite crystals in particular are often deeply honeycombed and in the cavities thus formed are later crystallizations of hair-like riebeckite, ilmenite, quartz, and fluorite. Some of the broken surfaces of the fragments have received a later growth of quartz parallel to the original quartz crystals of the fragment. The hair-like riebeckite, often suspending minute, pierced quartz crystals, frequently form beautiful clusters on the free surfaces of the fragments or in small cavities. Crystals of parisite are implanted in the same way on the fragments. Embedded in the crocidolite are casts of original fluorite octahedra sometimes partially filled with a mass of riebeckite fibers and crocidolite originally contained in the fluorite. The casts are generally discolored or partially filled by brown wax-like material. The large riebeckite crystals of the coarse granite or pegmatite bordering the upper portion of the central pocket also show strong corosion. Here the usual lining of microcline and aegirite appears to have been either very thin, or more probably was broken off, since many fragments of coarser pegmatite with aegirite and microcline crystals attached to one side are found among the fragments in the pocket.

Below and somewhat to the east of the central pocket (not shown in the figure) and apparently continuous with the aegirite-microcline rock surrounding the pocket, is a considerable mass of a fine-grained, light greenish-white rock of quite unusual character. The microscope resolves it into: quartz, microcline, and albite, a little microperthite, accessory zircon, ilmenite, calcite, fluorite, rarely parisite and probably the rare-earth silicate, *beckelite*. The albite forms perthitic intergrowths with the microcline only to a small extent, but occurs abundantly in the form of slender, simply twinned crystals elongated parallel to the edge $001 \wedge 010$. In width they rarely exceed 0.06 mm., while the length varies from 4 to 20 times the width. These lie clustered around the microcline grains or between them and the quartz, often parallel to the margin and again projecting at random into them. They also occur quite thickly scattered through the microcline crystals, less commonly in the quartz. Their relation to the aegirite crystals is like that of plagioclase to augite in the diabases. Where the albite crystals lie together in parallel or sub-parallel position, their side lines are straight, but where they cross one another, or where they touch or penetrate microcline, quartz, or aegirite, the boundaries are sinuous and curiously irregular. The aegirite also includes, or is indented by the microcline.

The zircon is abundant for an accessory and lies mostly in the quartz. It exhibits much the same features as the zircon in the fine-grained portions of the main zone. The same is true of the calcite and ilmenite and the same alteration products are associated with them.

Associated with the zircon in the quartz is a small amount of a mineral whose properties are as follows: — color, pale yellow to almost colorless; habit, usually in rounded grains, but occasionally in sharp octahedra; cleavage, occasional, as prominent cracks, thought to be cubical; index of refraction, very high; isotropic. Unless this be some new species, its properties, as enumerated, point to its being the rare mineral, *beckelite*, a silicate of calcium and the cerium earths, discovered and described by J. Morozewiez from Balka Wali-Tarama, where it occurred in a dike-like apophysis of mariaupolite. The apophysis consisted of a sugar-grained groundmass of albite containing phenocrysts of nephelite and magnetite. (See Rosenbusch, Mikroscopische Physiographie, 1905 Ed., p. 395.) The occurrence of the parisite, also a calcium, cerium-earth mineral, in the pegmatite perhaps supports the identification of this mineral as beckelite.

An estimate of the percentages of the main constituents by the Rosival method, in this case only approximate, gave: quartz 26.1 per cent, microcline 22.5 per cent, albite 35.0 per cent, aegirite 14.2

per cent, remainder 2.2 per cent. This shows that the composition of this rock does not probably depart very far from that of the granite, although texturally so radically different. Figure 16 Plate III, is a microphotograph of a thin section of the rock and will illustrate its main features.

To what extent the texture of this rock may be original, and to what extent due to recrystallization under pneumatolitic conditions it is difficult to say. If original, we have a striking example of the strong contrasts of texture which may occur in a portion of a rock-magma rich in mineralizers, but not otherwise, so far as can be determined, very different in chemical composition. If a product of recrystallization, we see that there has been an almost complete separation of the potash and soda feldspars with the consequent destruction of the microperthite structure, as well as other minor changes.

Chemical Composition, Sequence of Crystallization, Origin.

Without an exact knowledge of the chemical composition of the pegmatites as a whole, a thing almost impossible to obtain, it is of course not possible to discuss with as much certainty as we could wish, the relationships that exist between the pegmatites and the granite. A careful consideration of the mineral composition of the two leads, however, to the conclusion that the pegmatites are decidedly richer than the granite in quartz, aegirite, zircon, fluorite, the rare earth mineral, parisite, and metallic sulphides. The central pocket in the Fallon quarry pipe, which was undoubtedly originally filled with water or water vapor, leads to the conclusion that the material from which the pegmatite formed was also richer in water or water vapor, a conclusion in keeping with the usual idea regarding pegmatites. Of the constituents present in the pegmatite in excessive amounts over those in the granite magma, the water or water vapor and the fluorine appear to be the only ones competent to have exerted an influence strong enough to have brought about any considerable variations in the texture of the two rocks. And after all it appears to be true in the present case, as has been suggested for other pegmatites,[6] that the main difference between the pegmatite and its granite is irregularity of texture in the former accompanied in part at least by a considerably greater coarseness of grain. In the present case there is also a remarkable zonal arrangement of parts as a further distinguishing mark.

The textural relations of the minerals in the pegmatites are, up to a certain point, identical with the granite, and show that a striking

[6] Bastin, Jour. of Geol., vol. 18, No. 4, 1910.

characteristic of both is the great overlapping of the periods of crystallization of the minerals. In fact, if we take into consideration the small included crystals of aegirite and riebeckite in the feldspar and consider them as original crystallizations from the magma, we are forced to conclude that all of the minerals have been growing during the entire period of the solidification of the rock. This overlapping of the crystallization periods appears to be a characteristic of rocks of this type.[7] If, on the other hand, we disregard the small included aegirite, and riebeckites, it seems clear that the feldspar and riebeckite were first to individualize from the magma. If aegirite be an original mineral, and there appears no adequate reason to think otherwise, its period of growth must have begun well back in that of the original riebeckite and extended beyond it. In portions of the pegmatites and granite where aegirite predominates, or where riebeckite is wanting, the aegirite appears to some extent contemporaneous with the feldspar but the greater part is distinctly later. Throughout the granite and the massive parts of the pegmatites, the aegirite is closely associated with the development of the quartz as is also the zircon. It has been generally noted in riebeckite rocks that zircon has crystallized from first to last. In the present case, the mineral does occur in the feldspar and riebeckite, but the bulk of it is characteristically associated with the quartz, indicating a preference to a late development.

Murgoci, in discussing the origin of riebeckite, in the article previously alluded to, assigns a rôle of the utmost importance to mineralizers and variations of pressure as factors controlling the formation of riebeckite and aegirite in rocks of the Quincy type. He advances the idea that the question as to whether riebeckite or aegirite develops in a magma of this kind, depends entirely on variations in the pressure and the amount of mineralizers "(Fl, Na, Ti, Zr, etc.)" obtaining, or present at any given point in the crystallizing magma. Mineralizers are, doubtless, a leading characteristic of such magmas, and were certainly present in the Quincy-rock magma, but the evidence thus far available does not seem sufficient to guarantee to these mineralizers so critical a rôle. In fact the evidence gleaned from the present investigation, while it does not in any way deny to mineralizers an important rôle in the crystallization of the rock, seems to argue against the hypothesis referred to. The two minerals are not dimorphous, for they differ sharply in chemical composition. The aegirite for example, contains, 31.86 per cent of Fe_2O_3 and 0.87 per cent FeO ; the riebeckite

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[7] Murgoci, Am. Jour. Sci., **33**, 133 (1905).

contains 14.51 per cent of Fe_2O_3 and 21.43 per cent of FeO. Or the aegirite contains 22.98 per cent of iron, the riebeckite, 26.81 per cent, a difference of 3.83 per cent. There is an even greater difference in the soda content, not to mention minor differences. To convert one into the other calls upon the mineralizers and pressure, besides oxidizing or reducing a considerable amount of iron, to actually affect a considerable change in the chemical composition. It seems more reasonable to assume that the development of one or the other of these minerals depends primarily upon the relative concentrations at a given point of the various constituents which go to form the minerals.

The separation, whether by actual crystallization or by some process of molecular segregation prior to actual crystallization, of the feldspar and a part at least of the riebeckite from the magma, had the effect of greatly increasing the concentration of the more volatile or liquid constitutents, such as water, fluorine, also silica, the aegirite radical, zircon, etc., in the residual portions of the magma. The habit which the minerals crystallizing from such portions of the magma might or may have assumed, also the habit of the main part of the feldspar and riebeckite, has been somewhat modified by movements in the rock, either during the later stages of crystallization or subsequently, or both. This is indicated by the straining and granulation of the quartz; the deorientation of the portions of the feldspar, particularly the marginal portions; the development (recrystallization) of the smaller albite crystals about and between the larger grains; the frayed, granular, broken or otherwise irregular character of the last formed riebeckite and aegirite. Evidence of strong movements, accompanied by solvent and crystallizing action, are to be seen in the presence of the fragments in the large central pocket of the Fallon pipe, in the solution and recrystallization recorded there, and in the many seams, now sealed with relatively coarse riebeckite, feldspar, etc., which cross the granite in many places; also in the small quartz veins cutting the granite in some of the quarries. There is also abundant outside evidence that the granite has passed through profound periods of dynamic disturbance since intrusion. It was during some period or periods of movement, accompanied perhaps by an increase of temperature and possibly by a recurrence of pneumatolitic activity, that the development of the greater number of the minute cavities and the crystallizations of aegirite and riebeckite in the feldspar is thought to have taken place. Their location is generally in positions most favorable to the penetration of solutions, viz. — along the boundaries of twinning or perthite lamellae, or along cleavage directions. Other crystallizations of like origin but varying habit lie about the borders of the aegirite-riebeckite

individuals, between the grains of broken quartz and in minute fracture zones. By admitting this mode of origin for these crystallizations we are at least relieved of the difficulty of explaining how the aegirite, with an undoubted tendency to develop in the main at a late period with or just preceding the quartz, should also have been the first secretion from the magma. It simplifies the sequence of crystallization. Future study of the porphyries, etc., associated with the granite will doubtless throw further light on this question.

The zonal structure of the pegmatites and the mineral composition of each shows that there was a progressive segregation of mineral-forming compounds. In each zone, however, we notice essentially the same sequence of crystallization as in the granite, as if such zone had to some extent at least crystallized as an individual unit.

Following out these considerations relative to the crystallization of the granite magma, etc., we may, perhaps, find a clue to the mode of the formation of the pegmatite masses. The earlier compounds which separated from the magma resulted in a gradual concentration of the more volatile and liquid constituents and of the elements or radicals which tend to accompany them. These, becoming segregated at certain points, determined by unknown local factors, tended to escape by rising through the surrounding material. In so doing they became elongated in form by reason of the drag exerted on their margins by the more viscous material enclosing them. Hence the pipe-like form. This idea of movement in the pegmatitic material finds support in the presence of the fluidal structure noted as characteristic of parts of the dark marginal zone. This structure also suggests that the band belongs perhaps as much to the granite as to the pegmatite proper, as does also its texture, mineral composition, and gradual merging into the granite through portions of its extent. The pipe in the Ballou quarry is far below even the present surface of the granite, nor is there any indication anywhere that these pegmatites ever succeeded in reaching the surface. They appear to have been imprisoned in the granite by its solidification.

While the exact process of formation of the zonal structure cannot be accounted for with certainty with our present knowledge of the factors determining rock differentiation and crystallization, the hypothesis which seems to the writers to be best in accord with the observed facts is as follows: — In the case of each pipe the entire mass of pegmatitic material from which they developed having segregated from the granite magma as above outlined, it retained by reason of its different composition (greater per cent of water, etc.) its liquidity and power for further differentiation, etc., and perhaps retained them even after the enclosing

magma had solidified. Further differentiation into more or less clearly defined and well characterized zones then took place within this material, possibly by a process of fractional crystallization, although we are inclined to believe that the differentiation preceded actual crystallization and that each zone crystallized as an individual. This process resulted in still further concentration of the silica, water, fluorine, rare-earths, etc., toward the center of the mass resulting finally in the quartz centers, and, in the case of the large Fallon quarry pipe, of a free space or pocket filled with a watery solution.

It may be noted here that the graphic-granite zone with its 60 per cent feldspar and 40 per cent quartz seems to depart rather widely from the proportions of these minerals supposed by Vogt and others to be nearly constant and to represent a eutectic mixture. The graphic-granite does not, so far as we can see, correspond either in its mineral composition or in its structural relations to the rest of the pegmatite, to a eutectic mixture of the minerals of the pegmatite. In fact, not only in the present case, but in graphic-granites in general, there appear to the writers to be serious, if not fatal, objections to their being regarded as eutectic mixtures. The idea is at present little more than an interesting speculation suggested by a resemblance in the texture to that of known eutectics among metals and a crude approximation in a number of cases to a constancy in chemical composition.

At some time subsequent to the solidification of the pegmatite as a whole, but while there was still liquid in the pocket containing fluorine and some dissolved mineral matter, movements took place in the granite which were sufficient to fracture the pegmatite, fragments of which fell into the pocket. This was followed by the period of resolution and recrystallization already noted as occurring in the pocket and its lining and believed to have been contemporaneous with a similar process in the massive pegmatite and the granite as well.

It is possible that some portion of the crocidolite formation may have taken place at a later period perhaps even subsequent to the formation of the present system of joint cracks in the granite. As Dale has pointed out and others observed, the joint cracks are commonly filled with riebeckitic crystallizations, often crocidolitic in character.

Part II. Special Notes on the Minerals of the Pegmatites.

Quartz. — Crystallized quartz is an abundant constituent of the central pocket of the Fallon pegmatite, individual crystals reaching a length of 30 cm. They are either smoky through included black needles of riebeckite, pale blue from inclusions of crocidolite, or quite colorless.

The smoky and blue crystals are invariably of simple quartz type, prism largely developed with positive and negative rhombohedrons; in the crocidolite the crystals are doubly terminated. Most of these crystals are deeply etched by solutions which have in some cases dissolved away the whole termination leaving a ragged pitted fragment; only occasionally has the etching been of a sort to leave solution planes and such as were seen were too rough to be measurable.

The colorless quartz crystals are of a later generation, are small and complexly developed, the following forms having been observed on the one crystal measured:

m$(10\bar{1}0)$, r$(10\bar{1}1)$, z$(01\bar{1}1)$, $\Gamma(40\bar{4}1)$, e$(50\bar{5}1)$, s$(11\bar{2}1)$, x$(51\bar{6}1)$, u$(31\bar{4}1)$, $(21\bar{3}1)$, $(53\bar{8}3)$, $(8.5.\bar{13}.5)$, $(32\bar{5}2)$.

The crystal measured was a right-handed one; left-handed crystals were equally abundant and both types are commonly twinned on the "Dauphiné law."

One very interesting phase of the development of quartz crystals is seen on the surfaces of fractured masses of graphic-granite which have evidently remained after fracture in a solution capable of supplying silica. The quartz of the graphic-granite has grown outward into the surrounding free space, the crystals parallel over considerable areas and with good lustre and a smoky or bluish color but much etched. Some similar but less abundant growth of feldspar and riebeckite could also be observed on the same fragments. Almost always these fragments of regenerated pegmatite are cemented by finely felted crocidolite and the quartz is only revealed when the adhering fibres are removed by vigorous scrubbing with a stiff brush.

The quartz in the central portion and in the massive parts of the pegmatite all contains strings and sheets of inclusions other than riebeckite, etc. These are either minute black particles or cavities. In the more freely developed quartz crystals of the pocket the fluid cavities and black inclusions do not seem to be as abundant and often there are almost none at all. The cavities are exactly similar to those in the granite except that they probably reach a larger size on the average. In shape they are round, elliptical, pear-shaped or irregular; rarely they have been noted with a dihexahedral shape. The cavities commonly contain bubbles which can often be made to move from side to side by turning the stage of the microscope in an inclined position. The largest cavity noted measured 0.02 mm. and the bubble 0.005 mm. Many cavities may be seen from .001 to 0.010 mm. in diameter, while the bubbles will in general range from one fifth to one third of the diameter of their cavity. The cavities are often discolored with a ferruginous stain.

The quartz of the massive part of the pegmatites is relatively or wholly free from the minute microliths of aegirite and riebeckite so abundant in the feldspar. It appears to have been the last mineral to develop in the normal crystallization of the pegmatite as well as in the granite, and also to have been the last mineral to cease its growth in the secondary deposition which took place in the pocket.

The Feldspars. — *Microcline* in well formed crystals of orthoclase habit makes up the greater part of the porous material near the great central pocket. The crystals range from a diameter of two and a half cm. downwards to mere crystal specks ; they are, however, very constant in habit presenting a remarkably cuboid form due to the dominant development of the base, clinopinacoid, and orthodome ; prism and unit pyramid, the only other forms found, being very subordinate in size. The faces are smooth and give fairly good reflections of the goniometer signal. The albite twinning, shown by microscopic study to be universally present is not apparent on the exterior of the crystals ; its presence makes the crystals sensibly monoclinic, however, and the measurements obtained approximate to those of orthoclase. Well formed Baveno twins are seen in a few specimens but most of the crystals are in clusters without apparent definite relation of the constituent individuals. The color of the microcline is white to pale ivory yellow. On faces of the prism, there is often a secondary coating of colorless glassy feldspar in parallel position to the main crystal which the microscope shows to be also microcline although its appearance strongly suggested the growths of albite so common on orthoclase from numerous localities.

Orientated sections, cut from the freely developed crystals of the pocket lining and from some of the larger crystals of zone C, show that the microcline is twinned after the albite law only and thus lacks the grating structure characteristic of microcline in general. In basal sections the twinning is seen to be very finely polysynthetic. The individual lamellae appear as short strips slightly elongated parallel to 010. Their boundaries are as a rule not sharp. The two sets of lamellae extinguish symmetrically on either side of the trace of the twinning plane at an angle of 16 degrees (average of 12 measurements). The clearer growths of later age are in parallel position to the older crystal and in them the twinning lamellae are often longer and more sharply defined. In the small microclines throughout the finer grained portions of the pipe the twinning is usually more sharply defined. The extinction in 010 sections was found from the average of ten measurements to be 5 degrees. Figure 17, Plate **3**, is a microphotograph, in polarized light, of a basal section of one of the microcline crystals from

the pocket, and Figure 16, Plate 3, one of an approximately basal section of a small microcline crystal in a thin section from some of the fine-grained portion of zone C. In these figures one set of lamellae are seen extinguished. Although there is some kaolinization, the crystals are as a whole quite fresh.

The microcline of the microperthite throughout the massive parts of the pegmatites, as well as in the enclosing granite, is also quite fresh. The relative amounts of microcline and albite appear to be fairly constant, the latter being slightly greater in amount particularly about the margins, and hence appears as the host. The microcline strips as seen in 010 sections appear as narrow bands with somewhat irregular outlines. They have the usual orientation, steeply inclined to the vertical axis, usually extend with fair continuity and variable width nearly across the width of the crystal, pinching out at or near the border. In basal sections they are commonly quite irregular in outline although they preserve in a general way a course across the crystal parallel to the ortho-axis. The twinning in the microcline, when present, is nearly always after the albite law only, "gitter" structure being rare. In many crystals the microcline strips show twinning throughout, in others a portion only of the strips show the twinning, while again a part of one strip will be twinned but not the remainder. There is a close similarity between the microperthite of the Quincy granite and its pegmatites and that of certain dike-rocks (aegirite-gorudite) from Norway. Brögger, Becke and Kloos [8] in writing of these dike-rocks from the neighborhood of Langesundfiord, Laurvik, Fredriksvarn, Lövö, etc., note that the predominant microperthite is a microcline — plagioclase intergrowth in which the microcline has the relations that orthoclase usually does. The microcline departs from the usual habit of granitic microcline in that the lack of the gitter-structure is altogether characteristic, the mineral being often untwinned, or again twinned after the albite law only. Microcline showing this particular habit of twinning has been termed moiré-microcline by Brögger to distinguish it from the more common "gitter-microcline." The general shape of the perthite lamellae and their manner of arrangement appears also to be much the same as in the Quincy rocks.

The *albite* throughout seems to have a composition not more basic than Ab_{95} An_5. Some measurements on the smaller separate individuals indicate that some of it may be nearer an albite oligoclase. The albite of the microperthite is characterized by its freshness and relative freedom from included black particles and cavities. As already noted

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[8] Zs. f. Kr., **16**, 54 et seq. (1890).

it usually strongly predominates about the outside of the grains, often forming the entire margin. It is generally very finely twinned, rather high magnifications being required for its clear definition. The twinning lamellae are usually broader and stronger in the marginal parts. The albite about the margins is often extended out into adjoining feldspar and quartz grains, and these parts are sometimes deorientated. Separate small crystals of albite, usually elongate in habit and finely twinned, are commonly found about the larger feldspar grains. These often penetrate into the adjoining crystals sometimes with sharp crystal terminations, particularly with reference to the quartz. With them are quartz and microcline and these smaller, interstitial grains in places form almost a groundmass for the larger crystals.

The peculiar relations of the albite to the microcline, quartz, and aegirite in the fine-grained rock lying below the central pocket in the Fallon pegmatite has already been described. It is especially noteworthy that albite is lacking in innermost portions of this pegmatite except in this fine-grained rock, and that here it is not in perthitic intergrowth except to a slight extent.

Inclusions in the Feldspar. — The feldspar of the pegmatite as well as the granite is remarkable for its inclusions. There appears to be a strong tendency toward regularity in their arrangement. Thus in sections they may be seen arranged roughly parallel to the twinning plane, the direction taken by the perthite strips, or to cleavage directions; again they appear to be wholly without definite arrangement. Aegirite and riebeckite microlites are both usually quite numerous, but their relative proportions vary considerably. It has often been observed that they are apt to be more abundant in the immediate neighborhood of large crystals of aegirite-riebeckite, and that they may in such cases even have an orientation exactly parallel to the large crystal. The riebeckite has the form of minute shreds or rods rarely exceeding 0.02 mm. in width and usually many times as long as wide. They sometimes form clusters. Strings of small crystals of riebeckite also occur along fractures in the feldspar. In optical character they correspond to riebeckite. Their prevailing color is a rather light to dark blue, often more or less smoky. The aegirite microlites vary much in size from grains whose dimensions are measured in thousandths to those measured by a few hundredths of a millimeter. Usually with a distinct elongation parallel to the vertical axis, they are often curiously irregular in habit. Sometimes particles of different sizes and shapes are arranged in strings following some definite direction through the feldspar. In color they are pale yellowish-green, or yellow to almost colorless when in very small grains. $\mathfrak{a}$ is always

parallel to the elongation and the extinction is very small. These have apparently been called epidote by Dale [9] and do suggest that mineral in appearance as does much of the coarser aegirite of the pegmatites. Epidote is, so far as observed, altogether wanting, a fact quite in keeping with the chemical character of the pegmatite.

The minute black particles, like occasional larger black grains, are probably mostly ilmenite or magnetite; some are hematite. They frequently give rise to slight reddish stains in their immediate surroundings. They are more common in the microcline than in the albite. Minute cavities are also abundant in the feldspar. These may be round, elliptical, almost rectangular, or amoeba-like in shape. Though sometimes partially filled with black, reddish or yellowish stains, they do not seem to have now any other filling.

Riebeckite. — Macroscopically the riebeckite is characterized by a black or bluish-black color, often rendered greenish by the associated aegirite. The crystals of riebeckite are prismatic, showing only outlines of the unit prism and occasionally a face of the clinopinacoid. Terminal faces were not observed. Measurements of the prismatic cleavage angle made on two fragments yielded identical values of 55° 5′, an angle considerably larger than that of common hornblende which is 55° 49′. A rather feeble tendency to part parallel to the base seems to be present. With the exception of the inclusions in the feldspar and some of the smaller crystals, the riebeckite is always intergrown with aegirite to a greater or less extent in the manner previously described. Where the riebeckite comes in contact with the feldspar and quartz, the two are always to some extent intergrown and as already noted small shreds or grains of riebeckite often lie near the contact sometimes with the same orientation as the larger grain. Again shreds grow out from the edge as if they were secondary growths. The riebeckite also usually contains abundant black particles and larger black oxide grains, presumably ilmenite. Occasional grains of feldspar, fluorite, and zircon are also included, and patches of carbonates, fluorite, ore grains, and zircon are often seen.

The deep color and strong absorption of the mineral makes the determination of its optical properties with any precision very difficult. This difficulty is increased by the fact that it has been found impossible after many trials to obtain entirely satisfactory sections of the mineral across the cleavage owing to its extreme brittleness. By the study of finely crushed material and thin sections the following characters have been made out:

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[9] Loc. cit., p. 49.

Ray near $c' = \mathfrak{a}$	Ray // to $b = \mathfrak{c}$	Ray near $a = \mathfrak{b}$
For sections 0.03 mm. or under, deep blue to bluish smoky green. For over 0.03 mm. nearly or quite black.	For 0.03 mm. thickness, very dark smoky green to almost black.	For thickness under 0.03 mm., yellow. For 0.03 and over, brownish yellow with a greenish shade.

Absorption $\mathfrak{a} < \mathfrak{c}$ much greater than $\mathfrak{b}$. For many sections intermediate in position between the front and side pinacoids, a peculiar dull, grayish blue (some might call this a drab or even see a violet tone of color) is seen. This is particularly true of thin cleavage fragments. In many sections parallel to the clinopinacoid it has been observed that the distribution of color is not uniform, the blue being seen in streaks parallel to the cleavage, or lying along lines crossing the cleavage, suggesting in appearance minute cracks along which there has been some slight chemical change. In such cases the remainder of the section had a dull green color. In the riebeckite from the pegmatites at least, such variation in color does not appear to be connected with any significant change in the chemical composition. Tests with the sensitive tint on very thin cleavage fragments show always a negative elongation. The extinction in 010 sections does not exceed 4 or 5 degrees, measured on the prismatic cleavage. Its accurate determination is rendered difficult by the strong natural color and strong dispersion of the mineral. A single section perpendicular to the prismatic axis was obtained sufficiently thin to yield, in convergent light, using a powerful illumination, a faint biaxial interference figure. The hyperbolae move well out of the field on rotation of the preparation, indicating a large axial angle. The axial plane bisects the acute angle of the cleavages. This is substantiated by the interference figure obtained from the 010 section which is clearly that of an obtuse bisectrix with the axial-plane lying parallel to the cleavage direction. The hyperbolae in figures from this section are faintly colored red and blue ; also interference brushes obtained from random sections are strongly colored red or blue indicating a strong dispersion, the exact character of which has not been made out. From the above it appears that the axial plane in this riebeckite lies *perpendicular to b*, 010, *an unusual relation for a hornblende*, while the acute bisectrix lies inclined by not over 4 or 5 degrees to c', and is negative. A determination of the index of refraction for the yellow ray $\mathfrak{b}$, by the immersion method, gave a value of 1.695 (sodium).

Chemical Composition. — Material for a chemical analysis was obtained from a single large crystal which appeared exceptionally free

TABLE I.

Nos.	1	2	3	4	5	6	7	8	9	10
Spec. Gr.	3.39	..	..	3.433	..	..	..	..	..	..
SiO_2	51.79	50.01	49.30	49.83	49.65	45.4	52.11	51.89	52.13	51.03
TiO_2	1.28	..	..	1.43	..	4.0	..	..	..	..
Al_2O_3	.68	..	..	.75[4]	1.34	..	1.01	..	..	..
Fe_2O_3	14.51	28.30	30.72	14.87	17.66	16.8	20.62	19.22	19.53	17.88
FeO	21.43	9.87	7.97	18.86	19.55	22.0	16.75	17.53	21.25	21.19
MnO	1.15	.63	..	1.75	..	..	..	..	..	..
CaO	1.28	1.32	2.75	..	3.16	4.2	..	.40	..	..
MgO	.10	.34	..	.41	..	0.6	1.77	2.43	.22	.09
Na_2O	6.15	8.79	By diff.	8.33[1]	7.61	6.7	(6.16)	7.71	6.26	6.41
K_2O	1.10	.72	9.26	1.44	..	..	..	.15	..	..
F	.20	..	..	..	..	..	..	..	..	..
$H_2O-115°$ C.	.10	..	..	.20	..	..	..	..	..	..
$H_2O+115°$ C.	1.30	..	..	..	1.67[2]	..	1.58	2.36[2]	3.95[2]	3.64[2]
Totals	101.26	99.98	..	97.87	100.64	99.7	..	101.69	99.74	100.24
Less $0=2F$	.09									
	101.17[3]									

[1] Including Li_2O.

[2] Total No. 5 and probably 8–9–10 are loss on ignition.

[3] The total is too high, a fault most difficult to avoid in the laboratory where it was made. In the summer when the windows have to be open the dust from innumerable trains and the street causes small increments, chiefly silica, to accumulate. — C. H. W.

[4] ZrO_2.

No. 1. Riebeckite, from pegmatite, Fallon Quarry, North Common Hill, Quincy, Mass., U. S. A. Analysis by Warren.

2. Riebeckite, Island of Socotra. Analysis by Sauer, Z. D. G. G., **40**, 138 (1888).

3. Riebeckite, Island of Socotra. Analysis by Sauer, ibid.

4. Riebeckite, Colorado, U. S. A. Analysis by Koenig, Zs. Kr., **1**, 430 (1877).

5. Riebeckite, Cape Ann, Massachusetts, U. S. A. Analysis by Dr. J. F. McGregory. Quoted by Rosenbusch, Mikr. Phys., p. 341, from private correspondence.

6. Riebeckite, Red Hill, New Hampshire, U. S. A. From Paisanite, Pirsson and Washington, Am. J. Sci., **33**, 439 (1907). Calculated from the rock analysis.

7. Crocidolite, South Africa. Analysis by Doelter, Zs. Kr., **4**, 40 (1879).

8. Crocidolite, South Africa. Analysis by Renard and Klement, Bull. Ac. Belg., **8**, 530.

9. Crocidolite, Cumberland, Rhode Island, U. S. A. Analysis by Chester and Cairns, Am. J. Sci., **34**, 108 (1887).

10. The Same as No. 8.

from impurities. This was broken up and carefully picked over by hand under a powerful glass. When examined under the microscope it appeared agreeably free from alteration and included grains, except some inevitable black dust and a few black oxide particles as well as a trace of aegirite and microcline. The average of closely agreeing duplicates is given in column 1, Table I. For comparison a number of analyses of riebeckite and crocidolite of similar composition from other localities are reproduced in columns 2–10. Several others have been omitted because their large content of MgO and CaO excludes them from a close comparison with the present type.

The Quincy mineral differs rather sharply from the Socotra variety in the relative proportions of ferric and ferrous iron, the latter being much higher in ferric and lower in ferrous oxide. The Colorado and Cape Ann varieties (this last is from an alkaline stock similar in many respects to the Quincy stock and distant from it some forty miles) are much closer in this respect, as is also that from Red Hill, although this contains a notable quantity of CaO. The crocidolite analyses (7–9) show a rather closer relationship to the Quincy mineral. The alkalies of the Socotra and Colorado minerals are also notably higher than those of the Quincy riebeckite which, however, is nearer to the values for these oxides in the case of the Cape Ann and Red Hill mineral and in all of the crocidolites. The water percentages are not satisfactory, and at least in the case of crocidolite undoubtedly represent in part hydroscopic water. Fluorine is probably present in all. With corrections made in the waters and fluorine the agreement in the analyses would probably be closer. For further comparison the molecular ratios derived from the above analyses are given in Table II.

TABLE II.

Nos.	1	2	3	4	5	6	7	8	9	10
SiO_2	0.863	0.833	0.822	0.830	0.820	0.756	0.868	0.865	0.869	0.850
Fe_2O_3 + a little Al_2O_3	0.097	.177	0.192	0.093	0.123	0.105	0.137	0.120	0.122	0.111
TiO_2	0.015	..	..	0.017	..	..	..	..	..	..
RO, chiefly FeO	0.337	0.176	0.168	0.278	0.326	0.391	0.262	0.296	0.299	0.300
Na_2O + a little K_2O	0.111	0.148	(0.150)[2]	0.149	0.123	0.108	(0.098)[2]	0.125	0.101	0.103
H_2O + F	0.082[1]	..	..	..	0.089[3]	..	0.083[3]	0.128[3]	0.217[3]	0.200

[1] H_2O above 115°. [2] By difference.
[3] Total, probably loss on ignition and therefore high.

If the TiO_2 is deducted, with a proportionate amount of FeO to form ilmenite, the ratios for the Quincy riebeckite (No. 1) may be appor-

tioned as follows : — $Na_2Fe_2Si_4O_{12}$, 0.582 ; $R_4Si_4O_{12}$; 0.834 ; SiO_2 left, 0.058. This may also be expressed by the ratio, $SiO_2 : R_2O_3 : (RO + R_2O + H_2O + F) = 8 : 0.90 : 4.76$. The excess of silica is considerable. What the cause is, is not clear. It may be due to impurity of the material analyzed. The potash seems rather high and may be in error. The presence of even a little feldspar or quartz in the sample would easily produce the apparent excess of silica as calculated. In the cases of several of the other analyses it is necessary, in order to make them correspond to the metasilicate formulae, to assume the presence of a molecule, $R''Fe_2Si_4O_{12}$ on account of the excess of Fe_2O_3. In any case, the ratios lack sharpness and are far from satisfactory. It seems highly probable, however, that if the fluorine and water were correctly determined, and the precise rôle which they play known (whether they are a part of the chemical molecules or are merely held in solid solution or both), also probably some minor changes made in the figures for some of the other constituents, the molecular ratios of these amphiboles would show satisfactory agreement and the formulae would correspond quite closely to the simple metasilicate molecules. Table III shows the molecular ratios apportioned among the molecules mentioned above ; also the percentages of the molecule $Na_2Fe_2Si_4O_{12}$ for each of the minerals whose analyses have been given.

TABLE III.

	1	2	3	4	5	6	7	8	9	10
$Na_2Fe_2Si_4O_{12}$	0.582	0.888	0.900	0.558	0.738	0.630	0.588	0.720	0.606	0.618
$RFe_2Si_4O_{12}$	..	0.174	0.252	..	..	..	0.234	..	0.126	0.048
$(R \cdot R_2)_4Si_4O_{12}$	0.834	0.294	0.252	0.668	0.838	0.785	0.612	0.858	0.812	0.984
Rem'nder SiO_2	0.058	0.022	0.072	0.134	0.087	..	0.014	0.044	0.025	0.086
Per cent of $Na_2Fe_2Si_4O_{12}$	42	68	69	43	57	44	45	55	47	47

The Quincy mineral (1), that from Colorado (4), from Cape Ann (5), from Red Hill (6), and one of the crocidolites (8) show perhaps the greatest similarity, although there is considerable divergence among even these. In every one but No. 6 there is an excess of SiO_2. The amount of the $Na_2Fe_2Si_4O_{12}$ radical varies from 69 per cent for the Socotra mineral to 42 per cent for the Quincy variety. Six numbers, 1, 4, 6, 7, 8, 9, fall below the average which is 51.7. Statements in the literature regarding the composition of riebeckite and crocidolite are to the effect that they consist essentially of the radical $Na_2Fe_2Si_4O_{12}$ with varying amounts of $R_4Si_4O_{12}$ and analogous molecules. While the former molecule is certainly essential, the above data indicate that we are not justified in considering it the predominant molecule.

Crocidolite and the Slender Blue or Black Amphibole Crystals of the Pocket. — As seen under the microscope the crocidolite appears as a tangled felt of the most exceedingly minute fibers, pale blue to almost colorless. **a** lies with the elongation, the extinction is apparently small, and the index of refraction for the ray vibrating perpendicular to their length seems to be the same, as near as can be told, as the yellow ray of the riebeckite. If the crocidolite be immersed in water the fibers straighten out in a most remarkable manner. The crocidolite is shot through and through with the slender black amphibole crystals and tiny quartz crystals. It is therefore impossible to get pure material for analysis. Some carefully picked material, freed from quartz, so far as possible, by hand, was analyzed for ferrous iron and was found to contain 17.8 FeO. This figure must be much under the true value, since considerable quartz weighed out with the crocidolite must have been dissolved during the decomposition with hydro-fluoric acid, and the content of hydroscopic water is undoubtedly large. Making allowances for these, the value for the ferrous iron is probably close to that found in the riebeckite.

The blue or black amphibole crystals occurring in the crocidolite, in pockets, and on exposed surfaces of the pegmatite fragments have the form of elongated, relatively flat prisms, deeply striated parallel to the elongation (parallel c′) but not so far as observed, terminated with definite planes.

The smallest of the crystals will measure in thickness but little more than the larger crocidolite fibers. The width may in general be said to run from 0.04 to 0.003 mm., although the larger crystals may sometimes be observed as wide as 1.5 mm. The thickness will vary from about one fourth to one tenth of the width. The majority of the crystals as they lie on the flat side are opaque except at the very edges. The pleochrism and absorption are the same as for the riebeckite and the index of refraction for the yellowish colored ray appears to be also the same.

Both the crocidolite and the minute prisms are believed to be near to or identical with the riebeckite in chemical composition.

Aegirite. — The aegirite of the central pocket is also prismatic in development, sometimes, and especially in the smaller crystals, showing distinct and measurable terminations. There is, however, even in the best crystals much facetting and curvature of part of the terminal planes, especially in those highly inclined to the vertical axis. The faces of the prism zone are generally plane and measurements of sufficient accuracy were obtained to make it clear that these crystals may be referred satisfactorily to the axial elements of aegirite as described

by Brögger. As a rule the smaller the crystal the better the quality of its faces; the best ones were minute needles of clear green color. Larger crystals are dark green to blackish green in color and often occur in subparallel groups, sheafe or rosette forms; many show fractures more or less healed or extreme bending.

Twinning on the orthopinacoid is common in larger crystals but is invariably associated with rounding and irregularity of the terminal planes to a degree that entirely precludes measurement.

The basal plane was not observed. The form series as a whole is much more like that of augite than like that described as typical for either aegirite or acmite. None of the forms supposed by Brögger to be peculiar to those species were discovered. On this account and because several of the forms determined have not been recorded for aegirite, since, moreover, this aegirite is shown by the analysis to be nearer to the theoretical aegirite molecule $Na_2Fe_2Si_4O_{12}$ than any previously described, it was deemed advisable to calculate the angles of the forms found on the basis of the axial ratio derived from these measurements, and they are accordingly presented in the following table together with the observed angles.

The axial ratio calculated from fifty faces of six forms on eight crystals gives the values of the first line below, with which may be compared the ratios of aegirite and acmite as determined by Brögger.

	a		b		c	β
Aegirite, Quincy	1.1044	:	1	:	0.6043	72° 27′
Aegirite, Norway, Brögger	1.0975	:	1	:	0.6009	73 09
Acmite, " "	1.0996	:	1	:	0.6012	73 11

TABLE OF ANGLES OF AEGIRITE, QUINCY.

	$p_0 = .5572$ Calculated.		$q_0 = .5762$ Measured.		$e = .3015$ Limits.		$\mu = 72°27'$	No. of Faces.	Quality.
	ϕ	ρ	ϕ	ρ	ϕ	ρ			
a 100	90°00′	90°00′	89°57′	90°00′	89°37′ – 90°04′			5	poor
b 010	00 00	90 00	00 37	90 00				1	poor
m 110	43 35	90 00	43 33	90 00	43 00 – 43 55			27	good
f 310	70 42	90 00	70 26	90 00	69 56 – 70 56			5	poor
u 111	55 50	47 06	55 54	47 08	55 17 – 56 16	46°54′ – 47°31		11	good
s $\bar{1}11$	–23 15	33 20	–23 40	33 24				1	fair
w 331	48 21	69 52	48 29	69 50	47 45 – 49 13	69 36 – 70 00		4	poor
λ $\bar{3}31$	–37 47	66 27	–37 46	66 42				1	poor
δ 551	46 31	77 10	44 46	77 57	44 02 – 45 31	77 30 – 78 25		2	v. poor
τ $\bar{1}12$	–5 32	16 53	– 5 51	16 50	5 16 – 6 19	16 40 – 16 57		5	good
s $\bar{3}11$	–66 44	56 50	–66 40	56 45	66 37 – 66 44			2	v. poor
d 131	26 09	63 39	26 40	63 48	26 19 – 26 52	63 34 – 64 03		3	good

The forms w(331), (551), ($\bar{1}$12), and d(131) are new to aegirite although all are known on augite. The habit of the Quincy aegirite crystal is shown by Figures 3 and 4.

The general mode of occurrence of aegirite in the massive parts of the pegmatites has been previously described and may be briefly summarized here as follows: — It is in almost constant association with the riebeckite, either intergrown with it in the body of the crystal, or more commonly about the margins, particularly the ends where it is usually very strongly developed. The vertical axis is commonly parallel to that of the riebeckite, though frequently there is no relation between the positions of the two. This relation to the riebeckite and its common occurrence with quartz indicates a strong preference for the late stages of crystallization. Its dominant habit is toward a decided prismatic elongation with a parallel or sub-parallel grouping of separate prisms, as has been noted with regard to crystals in the pockets. When in quartz good prismatic outlines are often noted, but terminations were rarely observed in the sections examined. Macroscopically, the color varies from a light, slightly yellowish green to dark, or even blackish green. In thin sections the color is seen to vary greatly even in a single and otherwise optically homogeneous fragment. The usual color is:

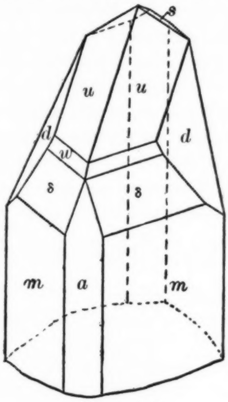

FIGURE 3.

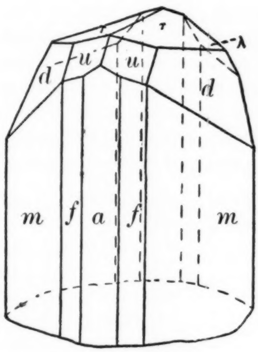

FIGURE 4.

$\mathfrak{a}$ = Pale to deep green, sometimes with a slight bluish caste: rarely almost colorless, particularly in one part of a crystal.
$\mathfrak{b}$ = Pale yellowish green to almost colorless.
$\mathfrak{c}$ = Pale yellow to pale yellowish green: almost colorless.

In many crystals the whole or a part possess a brownish-yellow or even reddish-yellow color. This is often most pronounced about black oxide (ilmenite) grains and is believed to be due to a pigment stain of ferruginous character. There at least appears to be no regularity in the distribution of the brownish and reddish colorations. $\mathfrak{a}$ makes an angle of 6° with c′, and other optical properties are the usual ones for this mineral. Twins parallel to *a*, 100 are common. A careful examination of aegirite from various portions of the different pegmatites indicates that it is identical in chemical composition throughout.

Chemical Composition. — The almost universal contamination of the aegirite with other minerals made the obtaining of suitable material for chemical analysis very difficult. By means of magnetic and heavy solution separations combined with hand picking under the microscope about three grams of material was finally obtained which showed as impurities only a little ilmenite and a trace of octahedrite and quartz. The analysis made in duplicate averaged as follows :

Aegirite, Fallon Quarry, North Common Hill, Quincy, Mass., U. S. A. Analyst Warren.

	Per cent.	Molecular Ratios.	
SiO_2	51.73	0.862	0.862
TiO_2	0.64	0.008	0.008
Al_2O_3	1.91	0.018	0.217
Fe_2O_3	31.86	0.199	
FeO	0.87	0.012	
MnO	0.60	0.008	
CaO	0.87	0.015	0.226
MgO	0.14	0.003	
Na_2O	11.43	0.184	
K_2O	0.40	0.004	
H_2O	0.20		
F	none		
Total	100.65		

Specific gravity at 25° C. 3.499.

Although a portion of the TiO_2 was probably present as TiO_2 (octahedrite) most of it is combined with RO as ilmenite, and after deducting the TiO_2 and the proportionate amount of RO as ilmenite, the combined ratios are, $SiO_2 = 0.838$, $R_2O_3 = 0.217$, $RO + R_2O = 0.218$; or very nearly $SiO_2 : R_2O_3 : RO + R_2O = 4 : 1 : 1$. This is almost exactly the ratio of the compound $(R''_2R)\,Fe_2Si_4O_{12}$. So far as known to the writers the ferrous iron is lower in this aegirite than in any hitherto analyzed, and the composition approaches very closely to the theoretical

composition of the compound $Na_2Fe_2Si_4O_{12}$ which is SiO_2 52 per cent Fe_2O_3 34.6 per cent, Na_2O 13.4 per cent.

Parisite. — The occurrence of the rare fluo-carbonate of calcium and the cerium earths, parisite, as a pneumatolitic mineral in the Quincy pegmatites is a new and interesting one. A closely related mineral, synchisite, associated with the barium-parisite, cordylite, has been described by Nordenskiold[10] and Flink;[11] it occurs at Narsasuk, Greenland, implanted on feldspar and aegirite or in cavities in pegmatite, an occurrence identical with that at Quincy.

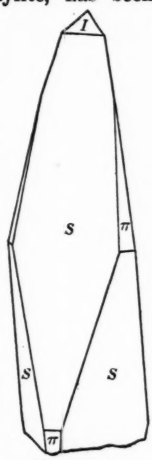

FIGURE 5.

Parisite has been found both in the Ballou pegmatite where it occurs only as grains in the massive rock, and in the Fallon pegmatite pipes where it is relatively abundant in all parts of the pipe where open spaces are present, implanted on the surfaces of the microcline and aegirite crystals. It also is found to some extent on the fragments in the central pocket. The crystals of parisite are generally sharply formed and of prismatic habit, ranging from extremely slender columns as much as one cm. long to short, stout, prismatic individuals scarcely longer than broad. The color is clear amber yellow in fresh crystals, dull yellow to brown and opaque when altered as it not unfrequently is. Such altered crystals show a perfect basal cleavage and pearly lustre on the base, both of which properties are entirely absent in fresh material. The same dependence of cleavage upon chemical alteration was found to exist upon parisite from Muso, the type locality, so that cleavage is undoubtedly a secondary property in this mineral.

The crystals are invariably striated horizontally and show infinite variety in the detail of individual development. They are either trigonal or hexagonal in cross-section; in the former case steep rhombohedrons being dominant, in the latter second-order pyramids. In neither case are actual prism planes more than rudimentary, the pseudoprisms being bounded by oscillatory combination of the steeply inclined rhombohedron or pyramid faces. The termination is generally a large and brilliant lustrous face of the pinacoid; sometimes, however, the relative size of this plane is much reduced by the presence of low rhombohedrons and second-order pyramids which either slightly truncate the edges between base and pseudoprism or may be developed

[10] G. For. Forh., **16**, 338 (1894).

[11] Bull. G. Inst. Upsala, **5**, 81 (1901); Med. om. Gronland, **14**, 236 (1898).

to such a degree as to give a pointed trigonal or pyamidal termination. Many crystals were measured and a very complex form series was found to be present, full details of which are to be found elsewhere.[12] It may suffice to state here that parisite was found to be undoubtedly rhombohedral in symmetry and to be referable to axes having the ratio a : c = 1 : 1.2912. The forms of most prominent occurrence are the base and second-order prism, c(0001), a($11\bar{2}0$),

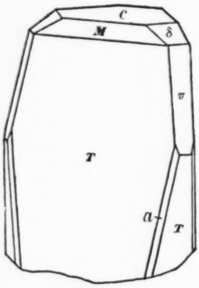

FIGURE 6.

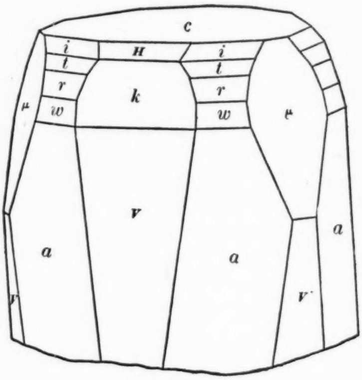

FIGURE 7.

second-order pyramids, ($11\bar{2}3$), ($5.5.\overline{10}.12$), ($44\bar{8}9$), r($22\bar{4}3$), ($44\bar{8}3$),
positive rhombohedrons, ($4.0.\bar{4}.15$), ($20\bar{2}5$), ($50\bar{5}4$), k($20\bar{2}1$), s($30\bar{3}1$), ($10.0.\overline{10}.3$), ($50\bar{5}1$), ($60\bar{6}1$),
negative rhombohedrons, ($0.3.\bar{3}.10$), ($0.9.\bar{9}.25$), ($02\bar{2}1$), ($05\bar{5}2$), ($03\bar{3}1$), ($04\bar{4}1$), ($06\bar{6}1$),
scalenohedron ($4.2.\bar{6}.11$).

Figures 5, 6, and 7 show typical combinations.

The relation of the position here adopted for the crystals of parisite to that formerly used (as in Dana, System, p. 290) may be stated thus: the former second-order pyramid series corresponds to the rhombohedrons of the new position; the former unit pyramid p($10\bar{1}1$) receives the new symbol p($11\bar{2}1$), the former second-order pyramid g($11\bar{2}3$) becomes the new positive unit rhombohedron g($10\bar{1}1$).

Optical Properties of Parisite. — As seen under the microscope, very small crystals or fragments are a very pale yellow to almost colorless and show a barely perceptible dichroism. For crystals ½ mm. thick the

[12] Am. J. Sci., **31**, 533 (1911). Zeitschr. für Kryst., 49 (1911).

ω ray is bright yellow, often with a brownish tone; the ϵ ray is golden yellow. The absorption is $\omega > \epsilon$ slight. For crystals 1 mm. thick the dichroism and absorption is but slightly greater. Upon alteration the crystals become filled with a dusty product, are less transparent, and often exhibit a brownish or brownish-red stain of varying intensity.

The indices of refraction were determined by the immersion method using a barium-mercuric-iodide solution. The determinations were made on a number of perfectly clear, small crystals chosen on account of the uniform development of their prism zones; also upon one larger crystal ($1\frac{1}{2}$mm. in diam.) terminated by a perfect basal plane which made it possible to orientate the crystal and cut a section parallel to the prismatic axis. An attempt was made to measure the indices directly upon this crystal by means of the Abbe refractometer but without success owing to the small size of the section and its low degree of transparency. The fine striations parallel to the edge between the base and the prism stand out very sharply under the microscope and make it possible to orientate the crystals with great accuracy on the microscope stage. The values obtained with sodium light are given below, also those heretofore given for parisite as determined by Senarmont and those for synchisite according to Flink.

Parisite, Quincy. Warren.	Parisite, Muso. Senarmont.	Synchisite, Greenland. Flink.
$\epsilon = 1.757$	1.670	1.7701
$\omega = 1.676\ (\pm\ 0.002)$	1.569	1.6742
$\epsilon - \omega = 0.081$	0.103	0.0959

The Montana parisite, also crystals from Muso valley taken from the mineral collection of Harvard University were tested by the immersion method and their indices were found to correspond to the values given for the Quincy mineral. The older values given for the Muso mineral appear to be quite wrong. The ordinary rays for parisite and synchisite are almost identical. The extraordinary rays appear to differ by 0.0131. While the extraordinary ray for the Quincy mineral is probably not as accurately determined as the value for the ordinary, the error can hardly be as great as 0.0131, and the difference between the two minerals for this constant may be a real one.

Chemical Composition of Parisite. — About a kilo of fine-grained material recovered from the fragile lining of the central pockets was carefully washed and fractioned by means of screens, an electro magnet, and heavy solutions until a fraction was obtained weighing about ten grams and consisting largely of parisite mixed with more or less aegirite, octahedrite, feldspar, and quartz. From this about three grams of *clear*

yellow or *amber* colored crystals were separated by hand-picking under a powerful lens. Aside from a slight stain in a few crystals the only impurities visible under the microscope were minute adhering grains of octahedrite and aegirite hardly amounting to more than a trace.

The result of the chemical analysis made on these crystals is as follows :

Parisite, Quincy, Mass.
Analysist Warren.

CO_2	24.16	SrO	tr.
Fluor.	6.56	Na_2O	.30
Ce_2O_3	30.94	K_2O	.20
$(La, Di)_2O_3$	27.31	H_2O	tr.
Yt_2O_3	tr.	Gangue	1.02
Fe_2O_3	.32		102.21
CaO	11.40	less $O = 2F$	2.76
		Total	99.45

Spec. G. 4.320

The molecular ratios derived from the above analysis are : — $CO_2 : F : R_2O_3 : CaO = 0.549 : 0.345 : 0.178 : 0.205$. This may be written, $CO_2 : F : R_2O_3 : CaO = 3 : 1.88 : 0.97 : 1.11$ which equals very nearly $3 : 2 : 1 : 1$. This ratio leads to the formula $(R''F)_2\ Ca(CO_3)_3$, which is the same as that derived for the mineral by Penfield and Warren[13] from analyses of the mineral from the original locality, Muso valley, U. S. of Colombia and a locality in Ravalli Co., Montana. The chemical composition throughout of the Quincy mineral is very close to that of the parisite from the other localities mentioned. The formula also agrees with that derived for the barium-bearing mineral from Greenland. Synchisite, although identical with parisite in its crystallographic and essentially so in its optical constants and in the elements present, contains, according to the analysis of Flink, one more molecule of calcium carbonate, the formula for the synchisite being $(R''F)_2Ca_2(CO_3)_4$. It is true that the two minerals differ perhaps slightly in specific gravity and in the value for the extraordinary ray. The relationship deserves further investigation.

For a more complete discussion of the relationship of these minerals and the crystallography of the parisite, see a paper by Palache and Warren.[14]

Ilmenite. — Ilmenite occurs in moderate abundance in both the Ballou and Fallon pegmatites. It appears to have been of rather late

[13] Am. J. Sci. **8**, 21 (1899).

[14] Zeits. f. Kryst., 49 (1911), and Am. J. Sci., **31**, 533 (1911).

formation and is particularly associated with aegirite, as embedded xenomorphic plates, and groups of tiny crystals implanted on crevices of fractured aegirite crystals (Ballou quarry), and as clusters of larger crystals upon the walls of cavities left by the destruction of such crystals by magmatic resorption (Fallon quarry). The crystals are small, not exceeding a diameter of 2 mm. and are always very thin tabular in habit. A dull black coating of manganese oxide commonly gives them a lustreless appearance, but in two specimens brilliant crystals were obtained which, despite minute size, gave good measurements on the goniometer. Octahedrite is almost always sparingly present with ilmenite.

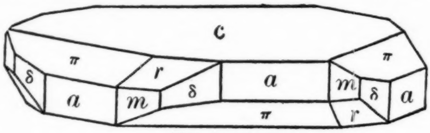

FIGURE 8.

The forms observed are as follows: c(0001), m(10$\bar{1}$0), a(11$\bar{2}$0), δ (21$\bar{3}$0),* θ (10$\bar{1}$9), u(10$\bar{1}$4), ξ (20$\bar{2}$5), r(10$\bar{1}$1), f(0.7.$\bar{7}$.20), e(01$\bar{1}$2), ∧(04$\bar{4}$5),* s(02$\bar{2}$1), λ (05$\bar{5}$2),* g(0.3.$\bar{3}$.11),* k(0.3.$\bar{3}$.10),* π(11$\bar{2}$3), n(22$\bar{4}$3). (* New forms.)

The crystals from Ballou quarry showed the forms c, m, a, δ, r, and π, the prism zone being well developed and the base large and very brilliant. The prism is new to ilmenite. Figure 8.

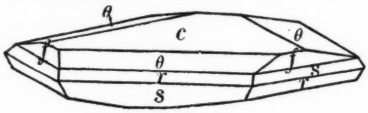

FIGURE 9.

Crystals from Fallon quarry are dominantly rhombohedral, prism faces being reduced to mere lines. The crystals measured showed the following combinations:

1. c, δ, r, f, e, s, n.
2. c, m, θ, ξ, r, k.
3. c, m, θ, r, u, e, k, π, n.
4. c, m, θ, r, n.
5. c, θ, ξ, r, e, g, ∧, λ, n.
6. c, m, θ, ξ, r, e, ∧, k, n.
7. c, u, r.

As shown in Figure 9, flat positive rhombohedrons are largely developed on these crystals, recalling the description of one (the common) phase of "Crichtonite" from Oisans by Descloizeaux.[15] That author considered the rhombohedrons which he measured, (10$\bar{1}$5) and (10$\bar{1}$9)

[15] Mineralogie, 2, 222 (1893).

and (1.0.$\bar{1}$.11) as negative but left the determination of sign doubtful. The second of these forms is common to all the crystals from Fallon quarry and is certainly positive, so both the others should be likewise so considered. Several negative rhombohedrons new to ilmenite were observed and are based on the following data :

	Form.	Calculated. ϕ	Calculated. ρ	Measured. ϕ	Measured. ρ	No.	Face limits of ρ.
g	(0.3.$\bar{3}$.11)	30 00′	23° 34′	30 00′	23°46′	3	23° 28′ to 24° 05′
k	(0.3.$\bar{3}$.10)	"	25 37	"	25 34	1	
Λ	(04$\bar{4}$5)	"	51 59	"	51 57	2	51 53 to 52 00
λ	(05$\bar{5}$2)	30 00′	75 57	30 00′	76 06	1	
							Limits of ϕ
δ	(21$\bar{3}$0)	10 53	90 00	10 30	90 00	4	10° 36′ to 11° 34

The presence on one crystal of the form f, observed before only by Solly on a Binnenthal crystal, confirms this form. All the forms present gave angles agreeing very closely with the values calculated from the axial ratio of Koksharow as used by Dana.

Chemical tests on the ilmenite from both quarries revealed strong qualitative reactions for manganese ; an analysis would be interesting but it was not possible to separate enough of the fresh mineral for this purpose.

Octahedrite. — Octahedrite is found chiefly in the large central pocket of the Fallon pegmatite, generally in close association with aegirite and often formed posterior to the alteration of that mineral since it is not infrequently seen on the walls of hollow casts of aegirite crystals associated with fluorite and ilmenite. Isolated crystals were also found implanted on feldspar crystals. The crystals of octahedrite are small, of a deep black color and of very brilliant lustre. They show only the forms c(001), m(110), p(111), k(112), and z(113), the two last the least common. These crystals are marked by two peculiarities ; they are in large part of prismatic habit with the first-order prism dominant, a habit not before described for this mineral and causing the crystals to be at first mistaken for zircon ; and they occur in cruciform twin groups with the form (101) as twin plane. The twins are sometimes complete interpenetrations of two equal crystals as shown in the figure ; sometimes but one end of each is developed ; again a larger crystal has a much smaller one in twin relation to it. The groups are exquisitely sharp and leave no doubt as to the definiteness of the twinning since the two upper faces of the unit pyramid of each crystal and the two lower, parallel and opposite faces to these reflect the signal simultaneously in

pairs ; thus the faces of (101) which are in zone with these unit pyramid faces must be parallel to the twin plane.

This twin law has been observed but once before on this mineral, on crystals from the titaniferous calcite-quartz veins of Somerville, Mass.[16] There twins were extremely rare, while here they are sufficiently numerous to be considered characteristic for the locality. Combinations of prism and unit pyramid are far the most common among these crystals. A few, however, show the base as a tiny facet and in a few

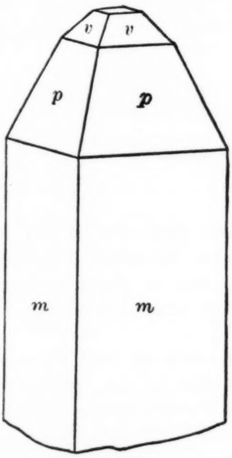

FIGURE 10.

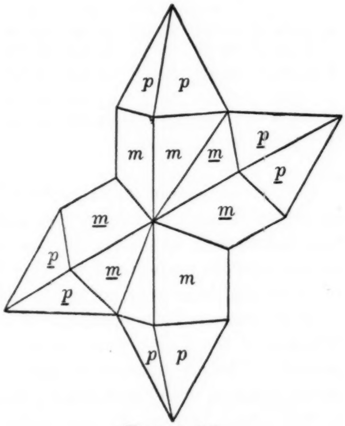

FIGURE 11.

the flatter pyramids k or z replace the acute summit of the common form. Figures 10 and 11 illustrate the habit of the octahedrite crystals.

Fluorite. — Mention has been made in preceding pages of the distribution of fluorite throughout all parts of the pegmatite masses. It is generally in small grains but near the central pocket, especially in that part where crocidolite was abundant the fluorite individuals were larger, one mass showing cleavage faces nine inches across having been found. Where wholly embedded in crocidolite the fluorite crystals are automorphic, octahedrons up to one inch in diameter thus occurring ; they are dull and somewhat rounded, the color a deep purple like all the fluorite of this locality, but occasionally there is a surface layer of

[16] On Octahedrite, Brookite, and Titanite from Somerville, Mass., C. Palache, Rosenbusch Festschrift, 1906, 311.

bluish green color due to included fibers of the blue crocidolite. The hollow casts left by the solution of such crystals have already been described.

In one or two cavities in the Fallon pegmatite there were seen tiny cubes of fluorite implanted on quartz, and in another such pocket, peculiar in containing also crystals of calcite, the cube was modified by two hexoctahedrons which appear to be new to fluorite. The measurements and derived symbols of these forms follow:

	Calculated.		Measured.		Limits.		No. of Readings.
	ϕ	ρ	ϕ	ρ	ϕ	ρ	
3.10.16	16°42′	33°07′	15°45′	33°20′			
3.16.10	10 38	58 26	10 36	58 33	10°30′ – 10°42′	58°30′ – 58°36′	2
10.16.3	32 00	80 58	32 04	81 05	31 52 – 32 16	80 50 – 81 20	4
259	21 48	30 54	21 01	31 15	20 45 – 21 18	31 11 – 31 19	2
295	12 32	61 32	12 32	61 25	12 27 – 12 37	61 23 – 61 26	2
592	29 03	79 00					

Calcite. — Certain small pockets in the Fallon pegmatite were filled by a final deposit of calcite. In one or two cases the calcite supplied was insufficient to wholly fill the open space and in these cavities calcite crystals were found showing the somewhat unusual combination of prism and base only, m($10\bar{1}0$) and c(0001).

Wulfenite. — Thin coatings of light yellow color as well as tiny crystals of Wulfenite were found on smoky quartz in the crocidolite pocket. The crystals are in part model-perfect combinations of first-order pyramid with third-order prism, n(111) and f(320), see Figure 6, p. 990, Dana, System, in part cube-like combinations of a prism and the base. The amount of wulfenite is very small and its presence is easily accounted for by the association in the same region of the pegmatite of molybdenite and galena.

EXPLANATION OF PLATES

PLATE I.

FIGURE 12. SECTION OF BALLOU PIPE.

The photograph shows a block cut from the pipe through its center about parallel to its axis (face marked A) and also across the axis (side marked B). The diameter is a little more than three feet. The concentration of dark silicates about the margin is very strong. The graphic-granite zone can hardly be distinguished from the main zone of pegmatite. The long dark prisms, more abundant toward the center, are of aegirite-riebeckite. The dark gray center is largely quartz. An indistinct radial structure may be seen.

FIGURE 13.

This is a part section across a portion of one of the Fallon quarry pipes. It was cut from a loose block and its exact location cannot be told. The height of the block is about three feet, but as the section is cut somewhat obliquely the actual width of the zones is less than that shown by the figure. D is a piece of the quartz center. C is the zone of coarse pegmatite with its large aegirite-riebeckite prisms. B shows the graphic-granite band, here very strongly developed. A is the marginal zone with a slight concentration of dark silicates along the inner margin. This band here is very similar to the granite and probably merges gradually into it.

Compare with Figure 1, page 133.

Fig. 12.

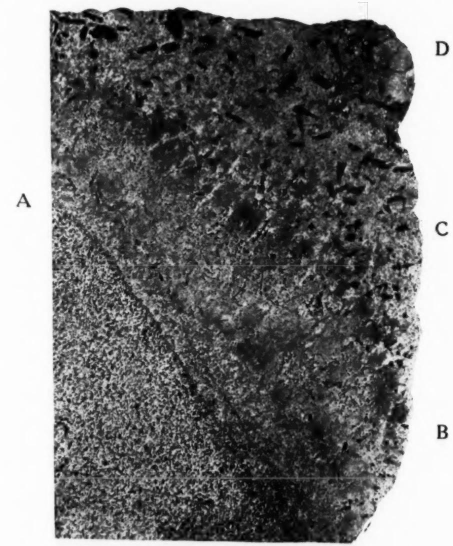

Fig. 13.

EXPLANATION OF PLATES

PLATE II.

FIGURE 14.

Microphotograph of quartz-zircon groups in the fine-grained portions of the pegmatite pipe in the Ballou quarry. In the lower right-hand quadrant one of these aggregates is seen with a well developed crystal outline. In this, the dark areas are zircon, the white, quartz. The surrounding material is quartz. Other groups above and to the left.

Crossed-nicols. Magnification about 120 diameters.

FIGURE 15.

Microphotograph of fine-grained rock lying just below and slightly east of the large pocket in the Fallon quarry pegmatite. Shows small lath-shaped albite crystals scattered through, and lying about, microcline grains. The smooth areas are quartz. Just between the two lower quartz grains is one of aegirite, also penetrated by the albite.

Crossed-nicols. Magnification about 120 diameters.

FIG. 14.

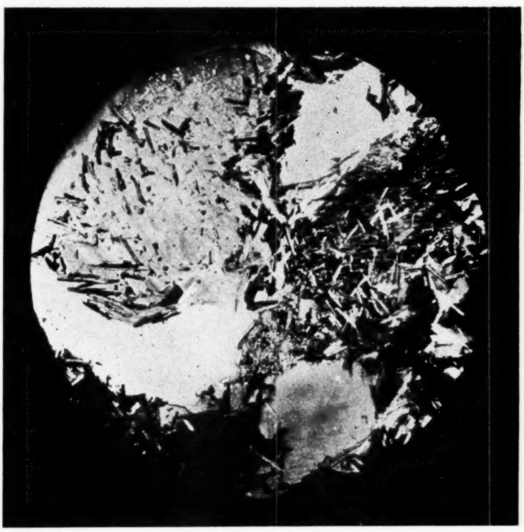

FIG. 15.

EXPLANATION OF PLATES.

PLATE III.

FIGURE 16.

Microphotograph of a small microcline crystal in the finer-grained portion of the main pegmatite zone. The section is approximately parallel to the base and shows twinning after the albite law only. One set of lamellae are in the position of extinction between crossed-nicols. Magnification about 150 diameters.

FIGURE 17.

Microphotograph of a basal section of microcline, cut from a freely developed crystal from the pocket. Shows twinning after the albite law only. One set of lamellae are shown in the position of extinction between crossed-nicols. Magnification about 350 diameters.

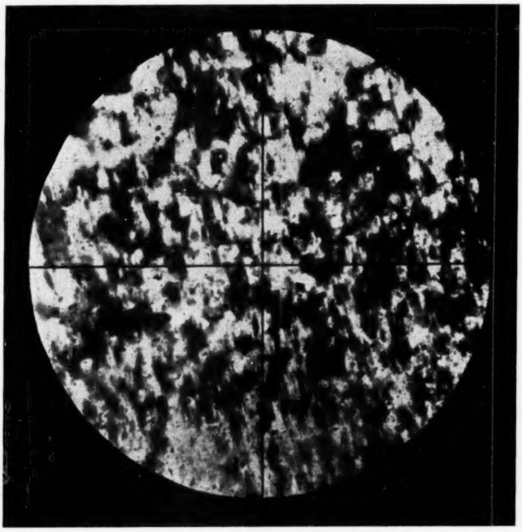

FIG. 16.

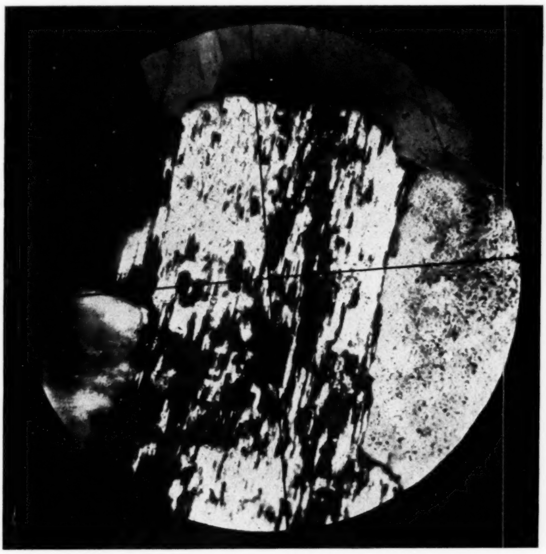

FIG. 17.